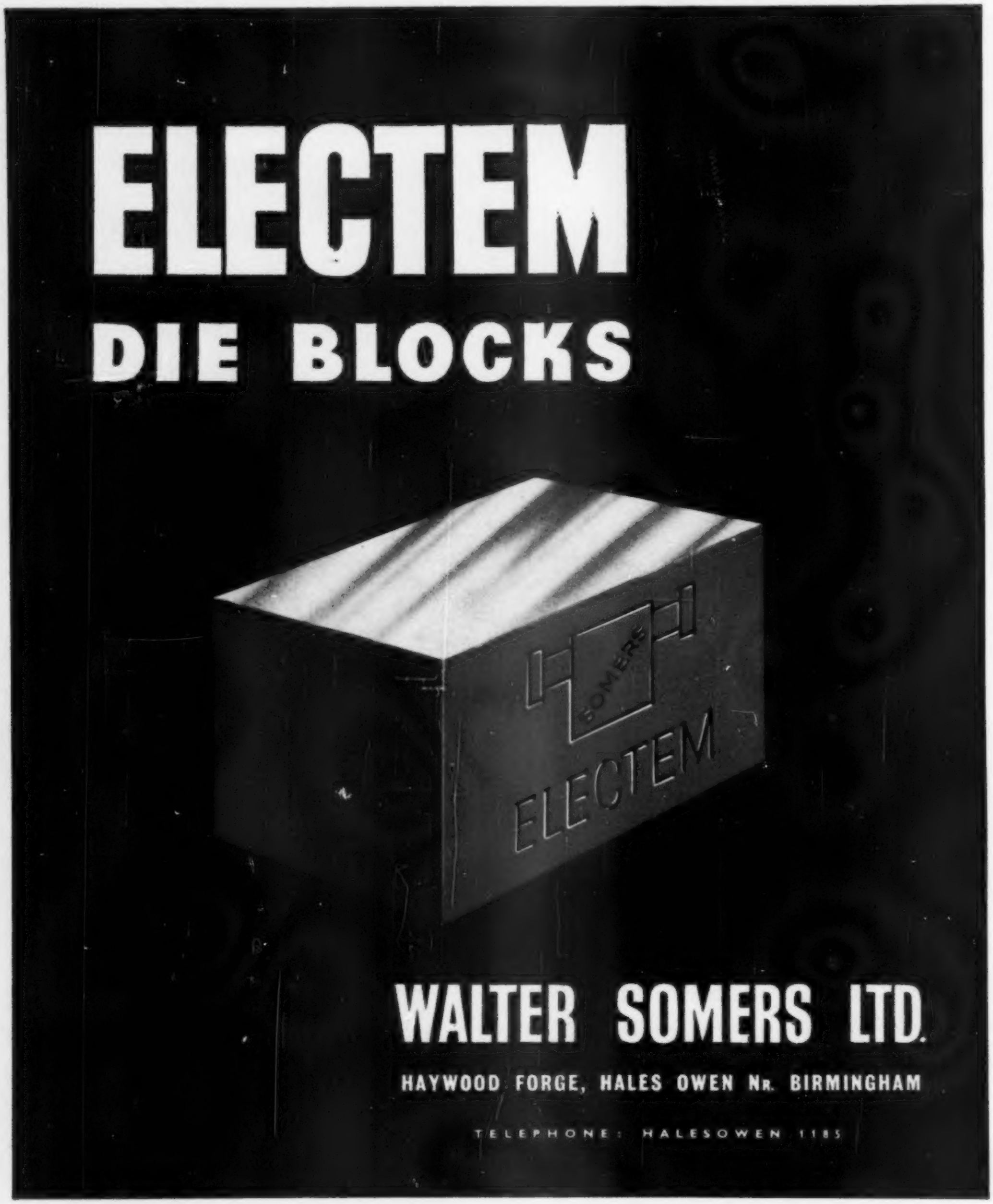
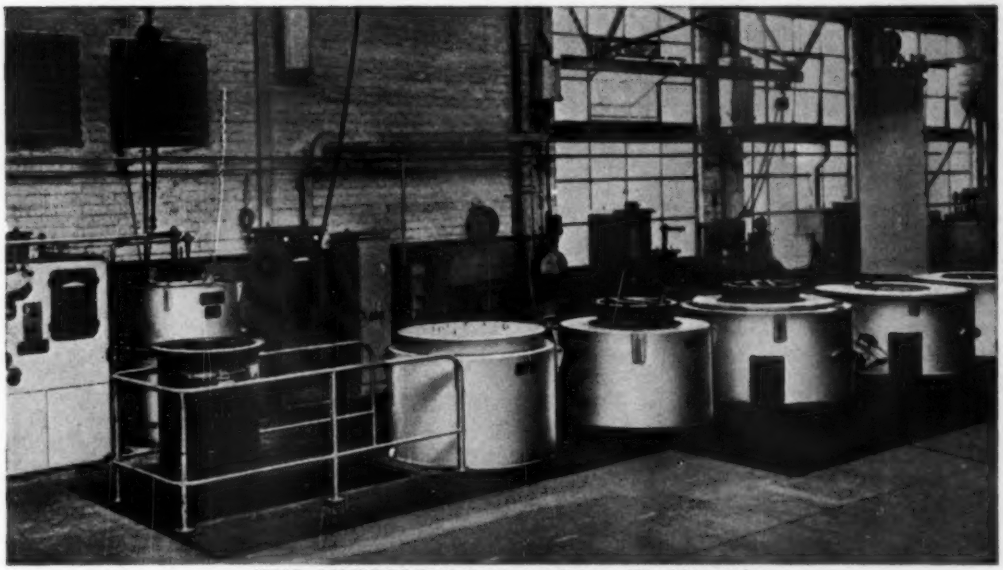
metal atment

Vol. 25 : No. 157 OCTOBER, 1958 Price 2/6


ELECTEM
DIE BLOCKS
SOMERS
ELECTEM
WALTER SOMERS LTD.
HAYWOOD FORGE, HALES OWEN Nr. BIRMINGHAM
TELEPHONE: HALESOWEN 1185



Wild-Barfield "P.T.G." Gas Carburising installation at Albion Motors Ltd.

They rely on

WILD BARFIELD

Gas Carburising at

Albion
MOTORS LIMITED

★ *Many of the components used in the manufacture of Albion motor vehicles are treated in Wild-Barfield Gas Carburising equipment.*

Precise control of depth and type of case is afforded by both Wild-Barfield gas carburising processes—the "P.T.G." and "Carbodrip" drip feed. By these methods carburising proceeds at almost the maximum theoretical rate. We will be glad to send you full details on request.

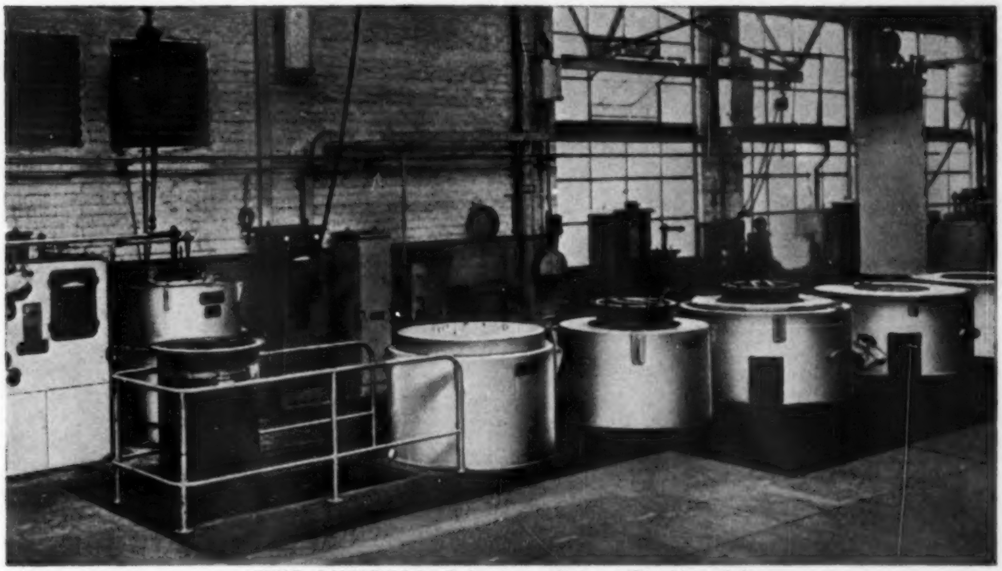
ELECTRIC WILD BARFIELD FURNACES

FOR *ALL* HEAT-TREATMENT PURPOSES

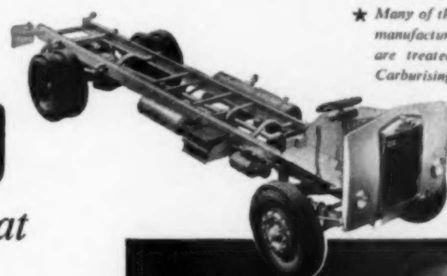
WILD-BARFIELD ELECTRIC FURNACES LIMITED

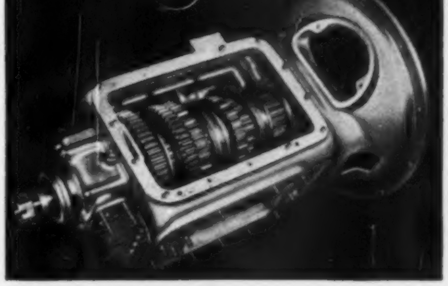
ELECFURN WORKS, OTTERSPOOL WAY, WATFORD BY-PASS, WATFORD, HERTS. Telephone: Watford 6091 (8 lines)

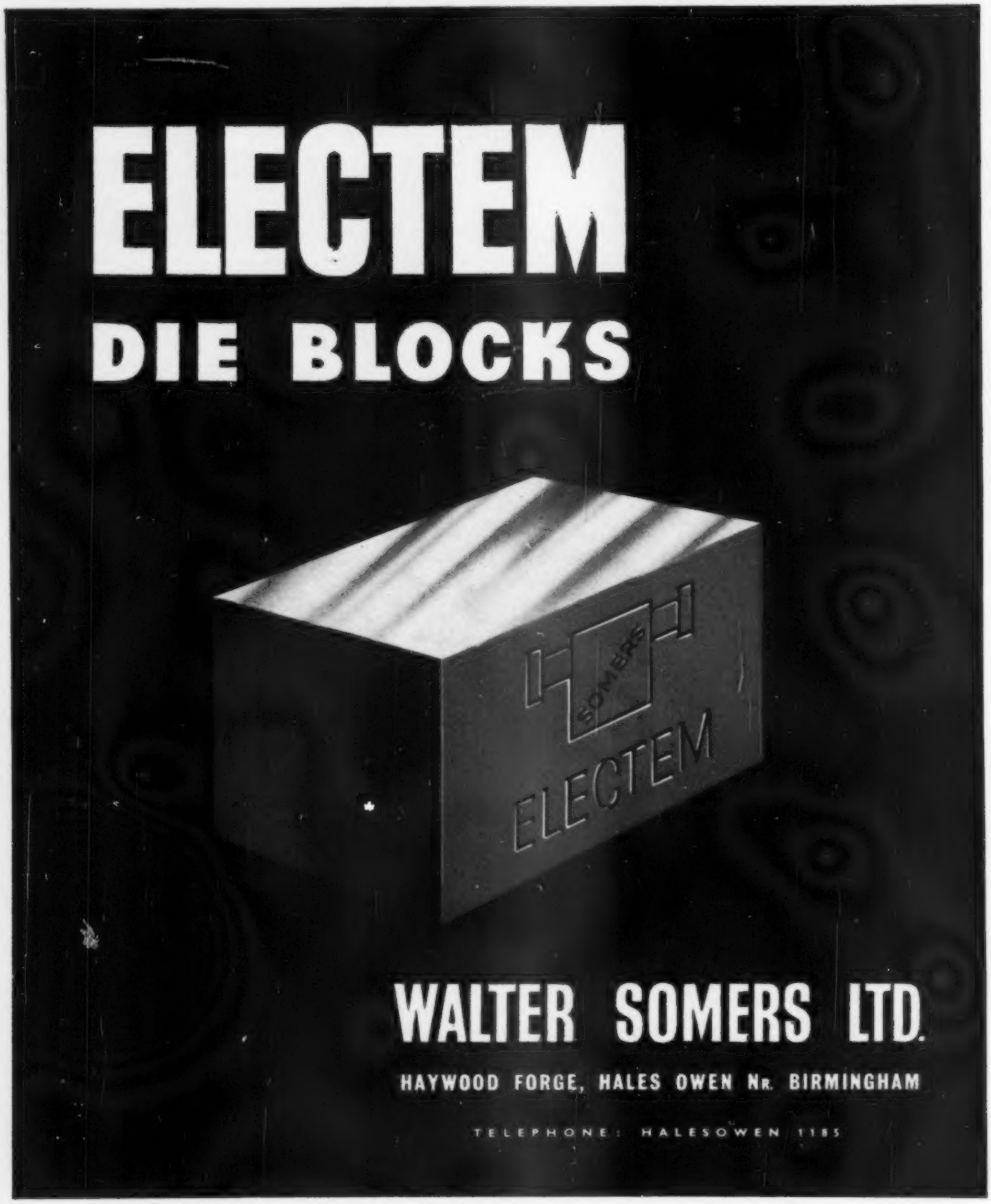
WB 58



Wild-Barfield "P.T.G." Gas Carburising installation at Albion Motors Ltd.






ELECTEM
DIE BLOCKS
SOMERS
ELECTEM
WALTER SOMERS LTD.
HAYWOOD FORGE, HALES OWEN Nr. BIRMINGHAM
TELEPHONE: HALESOWEN 1185


Morrisflex

I.C.I. USE A G.E.C.

VERTICAL CYLINDRICAL FURNACE

FOR BRIGHT ANNEALING 3 TON CHARGES OF COPPER STRIP

G.E.C. 275kW, vertical cylindrical furnace installed at the Kynock Works of I.C.I. Metals Division

For the heat treatment of non-ferrous metals and alloys the G.E.C. provides a comprehensive range of electric furnaces including both batch and continuous types fitted with high speed fans to provide forced atmosphere circulation. For the bright annealing of ferrous and non-ferrous metals and alloys in coils of strip or wire, G.E.C. vertical cylindrical furnaces are the obvious choice. Backed by twenty-five years' practical experience in bright annealing they combine consistent performance of the highest quality with the utmost economy.

FOR EFFICIENT PROCESS HEATING USE

G.E.C.

FURNACES · HIGH FREQUENCY · INFRA-RED

THE GENERAL ELECTRIC COMPANY LTD.,
MAGNET HOUSE, KINGSWAY, LONDON, W.C.2


'RESISTA 51'
SPECIAL ALLOY
STEEL PILGER ROLLS
"RESISTA 51"
assures
greater
output
and
reduced
maintenance
HADFIELDS
SHEFFIELD
HADFIELDS LTD., EAST HECLA WORKS, SHEFFIELD, ENGLAND.

cocking your own goose...

In the oven, the delectable bird wears a jacket of aluminium foil produced from Birlec furnaces. Heating of aluminium slabs for rolling is just one application of Birlec induction heating which saves floorspace, capital and production costs.

BIRLEC INDUCTION HEATERS with completely automatic mechanisation when required, are designed to suit extrusion, rolling and forging plant requirements.

BIRLEC

BIRLEC LIMITED

An A.E.I. Company

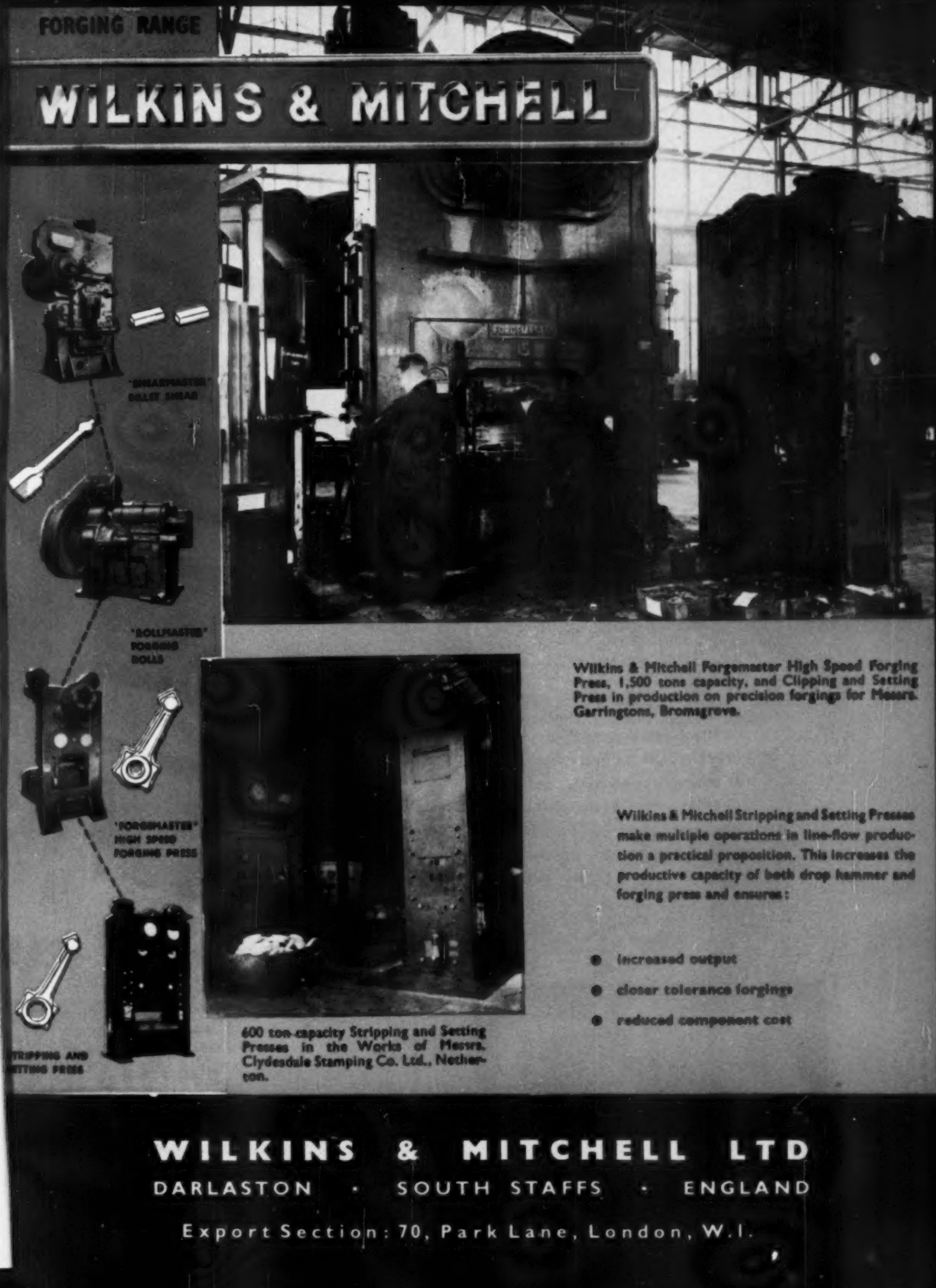
ERDINGTON : BIRMINGHAM 24

LONDON
SHEFFIELD
GLASGOW
NEWCASTLE-ON-TYNE

SM/B4112


EUMUCO
FORGING ROLLS
For pre-forging and finish forging at one heat.
AUTOMATIC FORGING ROLLS
For automatic production. Three or more stations and fitted with induction heating and shear positions
FORGING and CALIBRATING PRESSES
Fast stroking machines. Hot and cold forming with high accuracy.
For FASTER–
BETTER FORGING
CHAIN-LIFT DROP HAMMERS
Automatic operation with electronic programme control.
HORIZONTAL FORGING and UPSETTING MACHINES
With gripping and automatic bar feed for high speed working.
WICKMAN LIMITED
FACTORED MACHINE TOOL DIVISION, FLETCHAMSTEAD HIGHWAY, COVENTRY
Telephone: Coventry 74321

326 F 67/30



FORGING RANGE
WILKINS & MITCHELL
"SHEARMASTER" BILLET SHEAR
"ROLLMASTER" FORGING ROLLS
"FORGEMASTER" HIGH SPEED FORGING PRESS
TRIPPING AND ETTING PRESS
Wilkins & Mitchell Forgemaster High Speed Forging Press, 1,500 tons capacity, and Clipping and Setting Press in production on precision forgings for Messrs. Garringtons, Bromsgrove.
600 ton-capacity Stripping and Setting Presses in the Works of Messrs. Clydesdale Stamping Co. Ltd., Netherton.
Wilkins & Mitchell Stripping and Setting Presses make multiple operations in line-flow production a practical proposition. This increases the productive capacity of both drop hammer and forging press and ensures:
increased output
closer tolerance forgings
reduced component cost
WILKINS & MITCHELL LTD
DARLASTON · SOUTH STAFFS · ENGLAND
Export Section: 70, Park Lane, London, W.1.

Gear Hardening is one of the several production line operations for which Induction Heating is admirably suited. The right way to tackle the problem is to ask Delapena to put their Applications Department at your disposal.

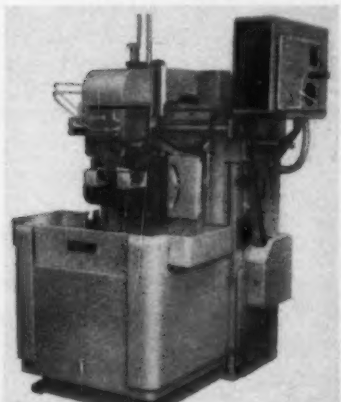
Getting your teeth into the problem

They will show, with particular reference to *your* manufacturing needs, how costs can be reduced by the elimination of grinding operations; how tooth profile can be finally hardened with the minimum of 'shape change'; and how a quieter and longer-lasting gear results.

To problems of repeat Hardening, Soldering and Brazing, Delapena Induction Heating Equipment can provide an economical answer.

Consult us now. Let us get *our* teeth into *your* problem.

This equipment, for example, is fully automatic and handles gears within a range of $1\frac{1}{4}$" to 26" diameter, 2 to 10 diametral pitch, face widths up to 8" and helical gears up to 30°.



Delapena

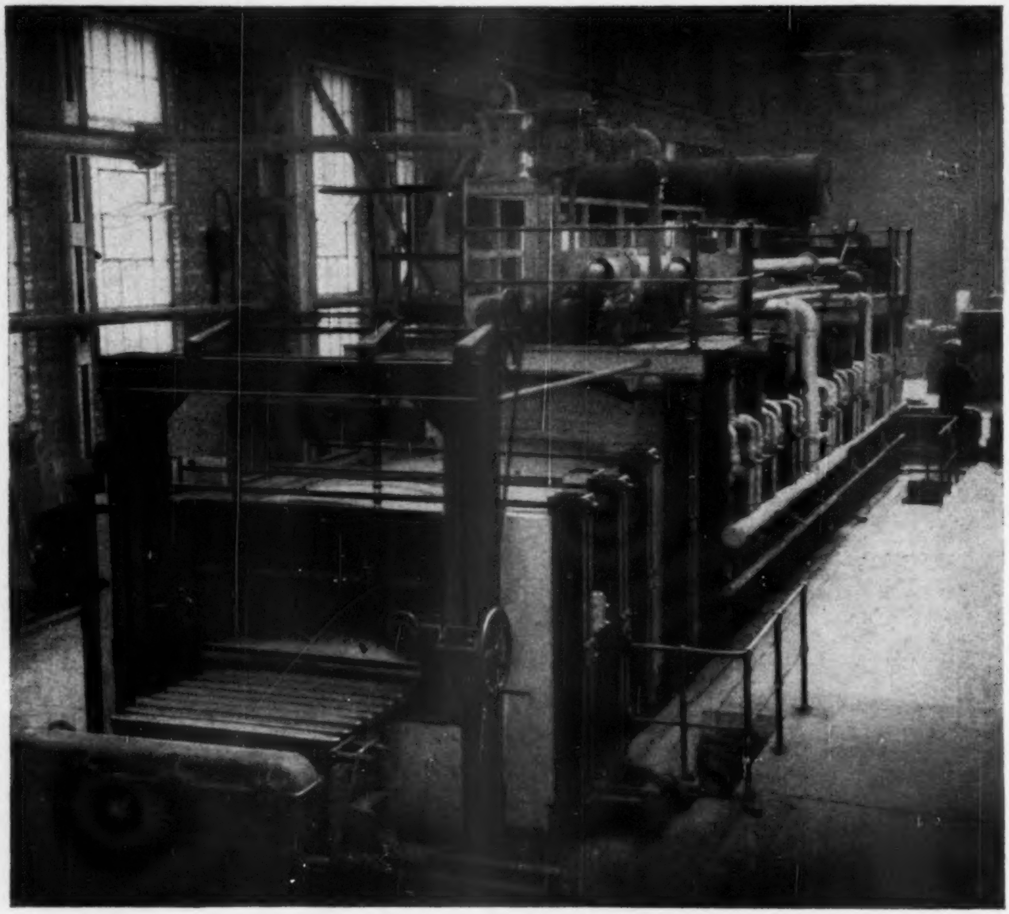
INDUCTION HEATING

DELAPENA & SON LIMITED

Manufacturers of Induction Heating and Precision Honing Equipment

ZONA WORKS · CHELTENHAM · ENGLAND
Telephone: CHELTENHAM 56341


SUMMIT
SUMMIT
SUMMIT
MILLING CUTTERS - SLITTING SAWS - HOBS
GEAR CUTTERS - END MILLS - BEVEL KNIVES
REAMERS - CIRCULAR SHEARING CUTTERS
PARTING OFF TOOLS - CIRCULAR FORM TOOLS



Metal treatment

and Drop Forging

October 1958

Vol 25, No 157

Official organ of the
NATIONAL ASSOCIATION OF DROP FORGERS AND STAMPERS

DFA

President J. H. SWAIN

Director A. L. STUART TODD, M A, J P

Grove Hill House, 245 Grove Lane
Handsworth, Birmingham 20
Telephone NORthern 3311-3
Telegrams Asdroforge, Birmingham

Published on the 15th of each month by

INDUSTRIAL NEWSPAPERS LIMITED

AN INDUSTRIAL NEWSPAPERS PUBLICATION

John Adam House
17-19 John Adam Street
Adelphi, London W C 2

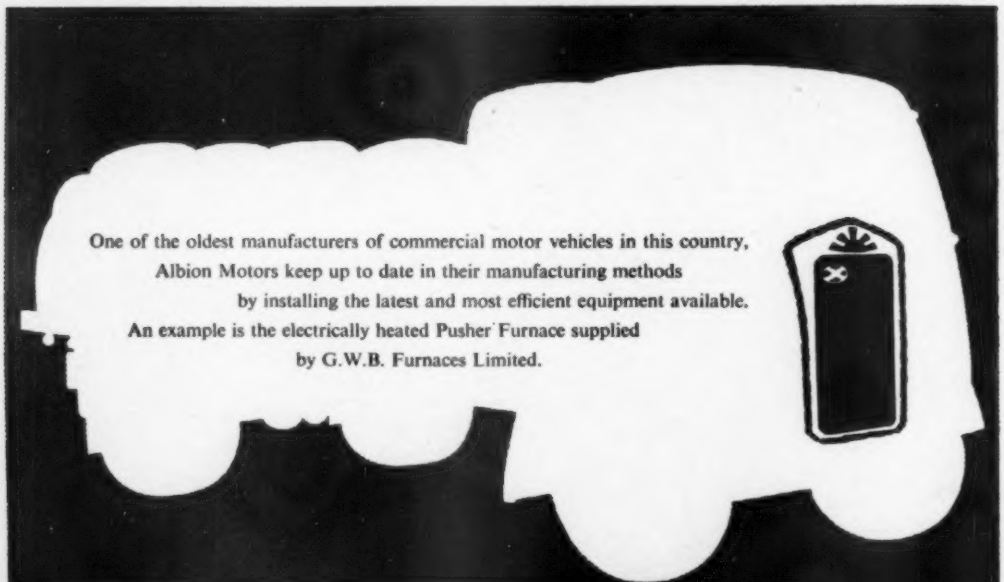
Telephone TRAfalgar 6171 (10 lines)
Telegrams Zacatecas, Rand, London

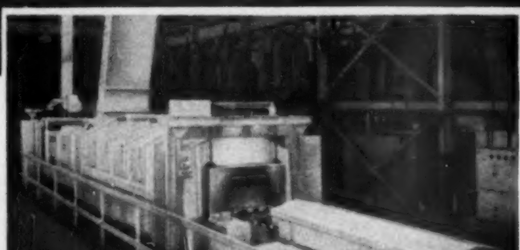
Subscription Terms Home and Overseas 30s per annum prepayable
Single copies 2s 6d (2s 10d post free)

CONTENTS

This journal is devoted to metals—ferrous and non-ferrous—their manufacture, properties, heat treatment, manipulation, testing and protection, with research work and development in all these fields

ALBION MOTORS AND G.W.B.





Overall view from charging end of 145 kw Pusher Type Normalising Furnace at Albion Motors Limited.

APPLICATION Various forgings such as main shafts, countershafts, pinion shafts and gear blanks are normalised by heating up to 900°C. and slow cooled down to 400/500°C.

AUTOMATIC OPERATION The only labour required is for placing the components into the charge trays at the entrance end of the furnace. By pressing a button, the following cycle automatically takes place. (1) The entrance door rises. (2) The pusher ram propels the loaded tray into the furnace. (3) The ram returns. (4) Entrance door lowers. (5) Exit door rises. (6) Hydraulically operated go-getter pulls last tray from exit end of furnace on to a cross conveyor. The cross conveyor moves the normalised parts to the top of an inclined roller track where the tray is unloaded by a tipper, and then returns empty to the entrance end of the furnace.

OUTPUT 600 lbs. of normalised forgings per hour.

G.W.B. FURNACES LTD.

P.O. BOX 4, DIBDALE WORKS, DUDLEY, WORCS. *Tel: Dudley 4284/5/6/7 & 5081/2/3/4/5.*

Proprietors: Gibbons Bros. Ltd. and Wild-Barfield Electric Furnaces Ltd. GWB215

Getting on with folk

IT is the lot of only a few men in our present day and age to perform their daily tasks in isolation. Highland crofters and Lakeland flockmasters are perhaps good examples, but these are men of a rare breed which shows every sign of becoming rarer. For most of us, work means continual contact with a greater or lesser number of our fellow mortals, with whom it is essential to ' get on ' in a reasonably amicable relationship. As our major industries become concentrated into a dwindling number of steadily expanding centres of investment, power and influence, the problems of human relationships in the industrial field become of paramount importance.

A great deal of investigation and case work has been undertaken in this field, but hitherto this has generally been carried out by specialist practitioners in the social sciences. Inevitably, these investigators have tended to express their findings in such a manner that these are more readily understood by fellow sociologists rather than by ordinary laymen or by specialists in some other branch of science and technology. It is of considerable interest therefore to note that a course is being organized at the Northampton College of Advanced Technology, in London, under the leadership of Z. M. T. Tarkowski on the direction and supervision of engineering and scientific personnel.

The fact that such a course is envisaged is all to the good. Hitherto it may have seemed that industrial psychologists were only interested in the behaviour of artisans and operatives, and that by and large, the aim and object of their teachings could be summed up as ' how to keep wage-earners happy and avoid strikes.' The proposed new course in London recognizes that it may be equally important (to put it rather crudely) ' how to keep executives from getting on each other's nerves ! '

The fact that people, even in the highest positions, and often with the best intent, do sometimes get hopelessly across each other is one which cannot be overlooked. In most cases probably one simply shrugs the thing off with a feeling of ' Oh well, it can't be helped !' In relatively small-scale undertakings this does no great harm. The dislocation and losses which may be occasioned by friction of this kind are not likely to reach dramatic or disastrous proportions. But, as the size of a business or an industrial undertaking increases, so proportionately do the risks involved in managerial quarrels increase. Particularly is this so where an industry carries heavy capital charges, where so many of the decisions of higher management have to be ' built in ' to the plant before it commences operation and where the results of a wrong decision can be terribly expensive in the end. It is significant to note that pioneering work of this kind is being done in this country in a very large ' business ' organization indeed—H M Treasury.

Gas carburizing and case hardenability

Some basic data

T. W. RUFFLE, F I M

Case hardening is now emerging from a traditional art to a controlled scientific procedure. The author of this article feels that there is now a lack of knowledge of fundamental steel characteristics which would enable more consistent results to be regularly achieved. It is hoped that this work done in the E N V Engineering Co's laboratories will stimulate further thought and investigation along these lines. The article will be concluded in next month's issue. Mr Ruffle, formerly with E N V Engineering Co Ltd, now represents Ipsen Industries, Inc in this country

FOR A PROCESS in such widespread employment, mainly on articles of importance, the fundamental data available on case hardening is notably incomplete; considerable omissions and even marked contradictions in the available literature are not difficult to find. Two important reasons for this may be suggested.

First, case hardening is a traditional craft with methods developed empirically; much investigation has concerned itself mainly with aspects of established practices, and the results of such practices, rather than with fundamentals.

Secondly, carburizing and hardening, together, constitute a complex process with a truly daunting array of important variables. In particular, pack carburizing, the major method even now and, until recent years, the only method, employs organic carburizing media, such as wood charcoal, which cannot be closely specified or defined.

All carburizing is, strictly speaking, gas carburizing—with a possible query about liquid-bath carburizing—but the term is normally used of applications where the atmosphere is separately supplied and externally controlled. Advances in furnace-building technique have made large-scale gas carburizing practicable in recent years. This has opened the way to better knowledge and control of the process, and made possible a less restricted approach to the whole of case-hardening practice. Gas carburizing, fortunately, usually leads to operating economy, but its major advantage is the opportunity presented for more precise control and greater flexibility.

The work reported here was instigated by a desire to have more detailed basic information on the author's carburizing practice in particular, but also to provide some general foundation for better knowledge of the influence of various details on final results. The carburizing was performed in a large continuous unit[1] from which a succession of test pieces could be handled with a strong assurance of consistent conditions for each specimen.

Considerations of size and cost alone mean that continuous-type carburizing furnaces will never be plentiful (although already those in regular operation in this country cannot be counted on one hand) but most horizontal batch-type carburizers and some pit-type furnaces operate under sufficiently similar conditions for the results below to have reasonably general application. For a selected wide range of commonly used case-hardening alloy steels, the programme was planned to investigate carbon absorption and distribution and the resulting hardness patterns. Yet another variation of the well-known Jominy end-quench method was devised to facilitate the latter.

Case hardening has two distinct phases; chemical, dealing with the amount and distribution of added carbon, and physical, the foundation for this being laid by the former. In practice the final pattern of physical properties (or, perhaps, one specialized aspect in certain cases) is the all-important object of the whole exercise, but, if such a desired pattern is to be closely reproduced consistently, the relative importance of the many controlling factors must be appreciated and appropriate control methods instituted.

As an illustration of this, surface compressive

One of the difficulties of undertaking human engineering work of this kind is that many of us possess an innate emotional resistance to it. Many normal adults heartily dislike the idea that if they undergo a course of instruction they will emerge better able to cope with their fellow men; they feel instinctively that any question of their ability to do this perfectly well anyway is a reflection upon their status of adult manhood—and in large measure they are perfectly right. There is no doubt that the well-rounded man does manage his affairs along these lines with an instinctive and inborn skill, owing nothing to external instruction. This is acknowledged tacitly by referring to such men as ' born ' leaders or ' born ' managers, and it is to people's credit that they hope at least that some such qualities may be found in themselves.

The existence of ' born ' leaders is one of the arguments sometimes put up against any sort of instruction in handling other people at all. A born leader, it is argued, will come to the top and lead anyway, why go to the trouble and expense of attempting to train lesser men to do the same? There may be some force in this argument, but against it one may consider a comparatively recent development in this field which is generally recognized as being highly successful—namely, marriage guidance. No one but a fool would contend that no ideally happy marriages existed before the Marriage Guidance Council came into existence, but at the same time it is equally certain that countless couples have been greatly helped and countless marriages saved from going on the rocks through the intervention of marriage counsellors. By the same token no instruction and training is needed to help the born leader to lead successfully and harmoniously, but instruction and training will undoubtedly be of assistance to those not lucky enough to possess these enviable inborn characteristics.

However, like all things, it is possible to carry the emphasis on the desirability of harmonious human relationships too far. In a recent magazine article the American critic Clifton Fadiman quoted the instance of an American professor who was asked whether a man could claim to be ' educated ' if, even though unable to do much more than read or write, he had been so psychologically conditioned that at all times he would work harmoniously with his fellows. The professor, after considering the matter, said ' Yes '! Clearly, this sort of thing won't do at all. While it is perfectly true that if executives are quarrelling, bickering and getting on one another's nerves generally, this may play havoc with the way in which a business is being run, it is equally certain that if their entire attention is devoted to keeping on good terms with each other then difficult decisions will be side-stepped, calculated risks will not be taken and the whole concern will be in danger of drifting into a state of hopeless stagnation. As in many things in life, it is the best of both worlds which has to be sought.

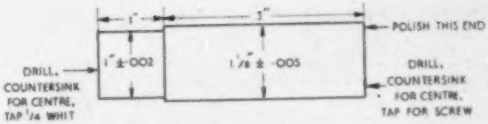
Test piece details

The full array of test pieces for a particular material is displayed in fig 1. From left to right these are:

Carbon gradient bar A suitable length of bar centred and turned accurately to 1 in. dia. The bar is suspended freely on a furnace tray fixture from the hole provided for the purpose and oil-quenched direct from the discharge vestibule. Softening is performed by immersion in a lead bath at 650°C and the bar cleaned by shot-blasting. The straightness is checked and, if necessary, rectified. Layers of selected thickness are then removed individually by turning and the carbon at each level determined, usually in duplicate, with a Strohlein apparatus.

Normal Jominy bar Made to standard dimensions but copper-plated all over to prevent carburizing. It is hung from a washer adaptor on a standard rack fixture on the trays. A Jominy quench fixture is located adjacent to the furnace discharge door and quenching is carried out in the normal way immediately on removal of the tray from the vestibule.

Carburized special Jominy bar Other workers[2, 3] have published results based on grinding flats to varying depths on case-hardened Jominy bars. A better and more versatile approach, since a cam-grinding machine was available, seemed to be the procedure indicated in fig 2 and illustrated at various stages in fig 3. The relationship of angle to depth was established carefully as shown in fig 4 and the simple set-up used when hardness testing is illustrated in fig 5. The lower 3 in. only seemed adequate; this was ground before carburizing to a suitable eccentric form and ground circular, leaving a witness, after hardening. Grinding flats is always



2 *Line drawing of special Jominy showing sequence of manufacture*

Procedure—(1) Turn; (2) Cam grind to special form on 3 in. length; (3) Assemble with washer at plain end, special screw at other end to mask centre; (4) Carburize and quench on Jominy fixture; (5) Remove screws to clear centres; (6) Grind 3 in. length circular leaving witness

difficult to do without affecting the surface hardness but 'circular' grinding is much less of a problem. As a further advantage, virtually duplicate tests can be made at any depth below the surface at choice, and normal practice was to take two series on opposite sides of a bar at the chosen depths and average the results.

Preliminary tests on uncarburized bars showed agreement within normal experimental error for bars of standard Jominy form and bars with the eccentric form.

Mass-effect test bars These were 3-in. long bars of varying diameters, ½ in., 1 in., and in some cases 1½ in. and 2 in. dia. They were carburized suspended from the drilled cross-hole and direct quenched by the automatic cycle on the furnace. After sectioning with great care to avoid affecting the structure at the mid-length, core-hardness figures and the case-hardness gradient (using 5 kg Vickers impressions on the cross-section) were determined.

3 *Series of special Jominy bars at various stages*

TABLE I *Analysis and grain size for steels*

Code letter	Specification	% C	% Mn	% Ni	% Cr	% Mo	Grain size	Source
A	EN 351	0·14	0·77	0·65	0·82	0·10	6—7	A
B	,, 353	0·18	0·86	1·14	1·07	0·12	6—8	,,
C	,, 355	0·19	0·64	2·10	1·77	0·23	6—7	,,
D	,, 362	0·20	0·78	0·45	0·61	0·14	7	,,
E	,, 36	0·14	0·45	3·18	0·82	0·14	6—7	,,
F	SAE 4620	0·20	0·58	1·82	0·25	0·22	6—7	,,
G	EN 351	0·18	0·76	0·72	0·78	0·03	6	B
H	,, 353	0·16	0·54	1·40	1·01	0·18	6—7	,,
J	,, 355	0·19	0·50	1·90	1·56	0·19	5—6	,,
K	,, 362	0·22	0·92	0·45	0·80	0·12	5—6	,,
L	,, 36	0·12	0·34	3·05	1·05	0·12	6	,,
M	SAE 4620	0·19	0·55	1·84	0·14	0·27	6—8	,,
N	,, 8620	0·19	0·62	0·44	0·70	0·10	7	C
O	1% NiMo	0·22	0·50	1·00	0·31	0·43	8, some 4	D
P	EN 39B	0·15	0·53	4·45	1·62	0·11	—	—
Q	M S	0·10	0·63	0·15	0·06	0·02	—	—
R	CH 65J	0·18	0·82	1·38	0·69	0·24	7	A

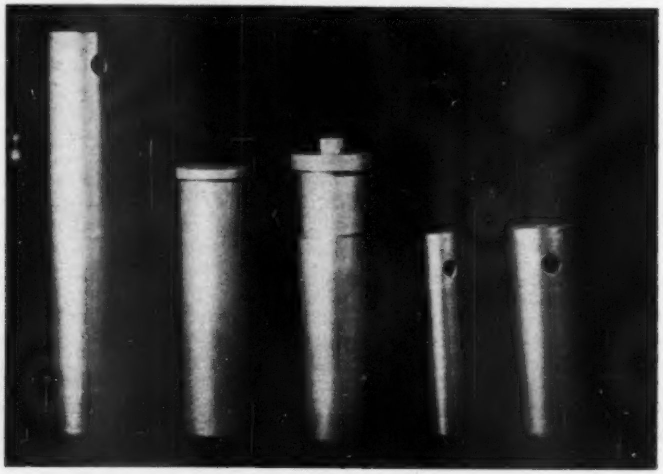
All Si contents in range 0·14—0·29%
All S and P contents below 0·03%
A—M inclusive, O and R all known to be electrically melted casts—others not known

stresses are a vitally important hidden asset in carburized components. Since this is so difficult to measure in itself and we know so little of the relative value of factors influencing this condition, it seems possible that considerable variations may occur in work apparently consistent to our normal tests unless care is taken to control all details of the process very carefully.

Details of steels used

Composition and grain-size details of all the steels used are given in Table I. The original selection comprised En 351, 353, 355 and 362 as a representative choice from the ' substitute ' range, and En 36 as the most popular of the old-timers. SAE 4620, in regular use by the author, was included as representing another popular type of composition. For this basic list, sufficient bar to carry out the visualized programme was kindly made available by each of two steel suppliers from current commercial casts.

Other additions were made later. SAE 8620 bar, made in the U S A, became available at an appropriate time and a sample was included. Two new compositions, a 1% Ni-Mo combination and another known as CH 65 J, a Ni-Cr-Mo variation, were also added. Finally, to give greater breadth to the carburizing series only, samples of En 39 and En 32 were added.



1 *Array of test pieces*

operate in sequence on the same time cycle. Both charge and discharge doors are protected with lock chambers and thorough automatic purging arrangements. Completed work may at choice be direct quenched automatically from the vestibule into an oil tank having vigorous directional circulation, or the tray may be manually extracted for work to be press-quenched or air-cooled.

Details of the actual times, tray arrangements and operating conditions for the two periods when the experimental bars were processed are set out in Table II.

Results and discussion

The accumulated results from this programme constitute a somewhat formidable mass of data and pose a serious problem for convenient presentation. Various aspects are dealt with in sequence below; results and comparisons derived from the data and elsewhere are used to indicate general trends and patterns.

Carburizing

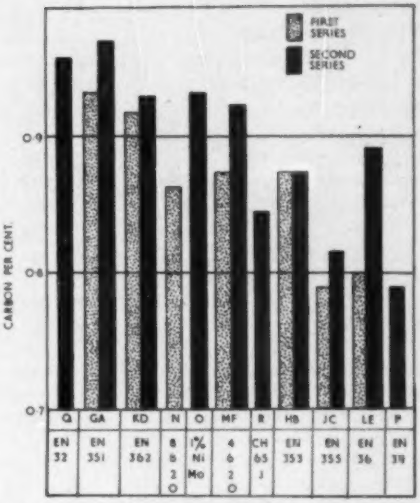
(1) *Maximum carbon content* This is a point of much interest as a major virtue of modern methods of carburizing is the ability to control the 'carbon potential' of the atmosphere and hence the maximum surface carbon content. It is not proposed here to dwell in any way on the control methods employed to this end as this has been amply dealt with by many other sources. There is a certain amount of published data on maximum carbon content but for very varied carburizing conditions. Harris[4] has a somewhat similar set of tests, but using pit-type furnaces and a richer atmosphere. Meyer [2] and others deal primarily with pack carburizing. It is none too easy to arrive at any positive conclusion from work on this point except fairly general agreement that nickel tends to reduce the carbon level and chromium can cause considerable increase. The A S M 1956 Handbook Supplement[6] indicates an expectation of 5% lower content for gas-carburized medium-alloy steels and 10% for higher-alloy steels—our own results will be seen to fall in line with this quite well.

The estimated surface carbon contents for all the specimens in this work are depicted in fig 6. The figure is obtained by extrapolating the carbon gradient determined by analysis to the surface, as may be seen in fig 7.

TABLE III *Correlation by Bravais-Pearson formula*

	Correlation coefficient	Probable error
Surface C%: Ni%	−0·66	±0·091
,, ,, : Cr%	−0·785	±0·062
,, ,, : Mo%	−0·093	±0·16
,, ,, : Ni + Cr + Mo%	−0·78	±0·063

[Correlation coefficient varies between 0 for no correlation and ±1 for 100% correlation. The level at which a given coefficient becomes significant varies with sample size. For this case, 17 samples, the level of significance is approximately 0·55.]



6 *Maximum surface carbon content for all specimens*

It seems that those specimens carburized in the second run tend to be slightly higher than those in the first; if we compare identical specifications (although the two runs were on different casts) we find none lower and the majority higher—averaging +0·04%C—in what were presumably the slightly richer conditions of the second series. Table II does, in fact, show a somewhat higher propane addition with marginally lower dewpoint for this second run.

The results demonstrate clearly that steels of higher alloy content carburize less richly at the surface. Under the conditions described, if we group the material somewhat arbitrarily, we find:

	Alloy	%C	Range
1 sample	None	0·97	
6 samples	Low	0·93 (average)	0·87/0·98
5 samples	Medium	0·89 (,,)	0·84/0·94
5 samples	High	0·85 (,,)	0·78/0·89

Perhaps the most interesting point is the low maximum carbon with En 355, a composition with rather high chromium content and normally considered prone to over-rich case. It seems that carburizing with this type of controlled atmosphere avoids this particular bogey; this should permit greater flexibility in choice of alloy and composition once steels can be considered on a basis of their reaction to controlled gas carburizing only.

Statistical estimates of the correlation between

TABLE II *Operating conditions during test piece carburizing*

	First series	Second series
Temperature—Control settings	Zone 1: 900°C ,, 2: 920°C Zone 3: 920°C ,, 4: 850°C	Zone 1: 900°C ,, 2: 920°C Zone 3: 920°C ,, 4: 850°C
Endothermic generator	No. 2: 875 c f h air; 125 c f h propane	No. 2: 875 c f h air; 125 c f h propane
Atmosphere: Supply to furnace — Zone 1	500 endo: 5 propane	500 endo: 6 propane
,, 2	500 ,, : 7 ,,	500 ,, 10 ,,
,, 3	300 ,, : 5 ,,	300 ,, : 5 ,,
,, 4	200 ,, : 0 ,,	200 ,, : 5 ,,
(total)	1,500 c f h endo: 17 c f h propane	1,500 c f h endo: 26 c f h propane
Furnace dewpoint checks	9—13°F (Alnor)	8—12°F (Alnor)
Times All trays—12 h 29 min	First: In 8.37 p m; out 9.06 a m Last: In 12.56 a m; out 1.25 p m	First: In 9.14 p m; out 9.43 a m Last: In 2.12 a m; out 2.41 p m

LOADING PATTERN THROUGHOUT

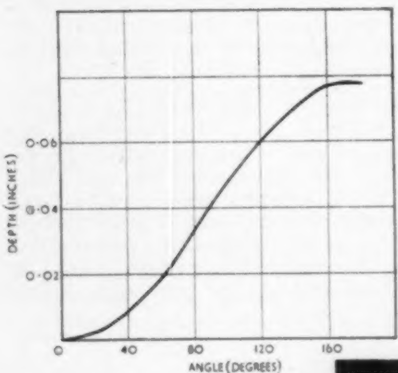
Track 1	Track 2	Track 3
Standard Jominy bar Production crown wheels	Special Jominy bar Carbon gradient bar Production crown wheels	'Mass effect' bar Production pinions

CARBURIZING SEQUENCE

First series:	G, H, J, K, L, M, N (in that order)
Second series:	A, B, C, D, E, F, O, R, P, Q

TYPICAL ATMOSPHERE ANALYSIS

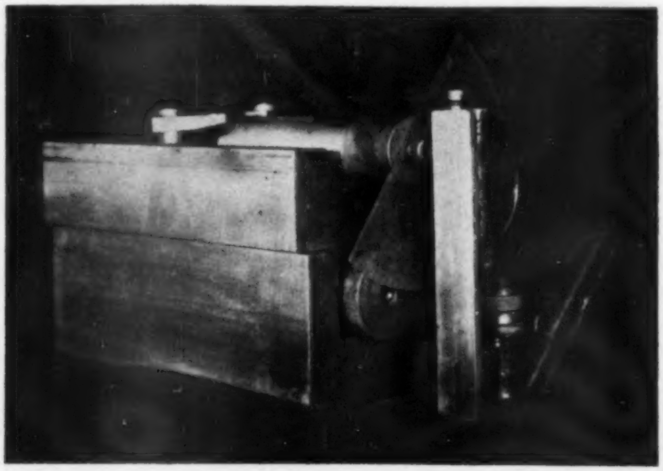
28·6% H_2: 22·7% CO: 1·0% CH_4: 0·1% CO_2: remainder N_2



4 ABOVE *Angle versus depth relationship*

Carburizing procedure

The test pieces were treated in a continuous, pusher-operated, three-track furnace, radiant tube heated in four zones, the atmosphere being endothermic gas made from air-propane with appropriate propane furnace addition. The three tracks as a general rule are worked at the same case depth and



5 RIGHT *Set-up for hardness testing*

The point at which the straight line intersects the base carbon line is termed the 'apparent case depth' (0·054 in. in the example), and it will be seen that the *added* carbon is the same for both this artificial gradient and the true one. The other development illustrated in fig 7 is dealt with in the next section.

'Case depths,' determined by this procedure, are given in Table IV and also summarized on a basis of the two carburizing batches and of alloy content. This demonstrates, again, some variation between the two experimental batches, the first series

TABLE IV *'Apparent' case depths*

Code	Depth	Code	Depth	Code	Depth
A	0·062	G	0·054	N	0·060
B	0·064	H	0·058	O	0·066
C	0·061	J	0·055	P	0·059
D	0·064	K	0·055	Q	0·059
E	0·060	L	0·055	R	0·060
F	0·065	M	0·057		

averaging 0·056 in. against 0·062 in. for the second. The most probable cause of this is a small variation in control temperature—the two batches were separated by an interval of nearly six months.

Variation, considered from the alloy-content angle, is very slight, high-alloy content appearing marginally less deep as might be expected; the difference, however, is much less than one would assume from some other published results, although these are based on other case-depth criteria.

The results of these determinations are reassuring from the point of view of practical operation, in that components of differing composition may be processed together without undue complication—remembering, however, that these considerations are on carbon content, not hardness.

Examination of variation in relation to the original carbon level of the various specimens shows no relationship within the rather limited range covered.

There is little point in comparing these depths on a time basis with those obtained elsewhere, since the conditions of operation, temperature sequence in particular, are very much an individual matter in these large units.

(3) *Composition gradient pattern* Another concept developed by Harris seems worthy of more thought and attention as a means of comparing processes. A 'dimensionless' derivation of a particular carbon gradient makes practical its comparison for 'form' with any other, regardless (within reason) of the actual case depth or the core and surface carbon figures. The method is illustrated and briefly explained in fig 7.

All 17 carbon gradients have been treated in this way and these results are shown in fig 8 as a curve drawn through the average for all results and a band including all extremes. The variation between the individual curves is quite small and no association could be found of such variations with original carbon content or with the level of alloy content.

Comparison is made in fig 9 with similar curves calculated from Harris's figures[4] and also from a set of varying alloy case-hardening steels carburized in an American continuous gas-carburizing furnace.[5] The full conditions for the latter are not available but are reasonably typical

There is a distinct difference in form between the curve derived from the present work and those from the other two sets of data. Over-much conjecture on this point is unwise on such rather limited evidence. One might anticipate that the alteration could be associated with differing carbon potentials; however, Harris's conditions gave higher surface carbon than the other American results (which were at a higher surface level than our own), yet the latter show a greater deviation from our curve than Harris. This seems to show potential as an ineffective factor in this matter.

It must be borne in mind, of course, that Harris's average covers carburizing carried out 870°C, 900°C and 925°C (three series each at constant temperature). His curves show no marked variation due to alteration in temperature. Temperature variation during the carburizing cycle may be a major influence on 'characteristic shape' with possible additional complication due to changing carbon potential in a final cooler zone. Clarification of this matter requires much more data and experiment which may lead to knowledge rather than opinion as to the form most desirable for a given purpose.

References

(1) T. W. Ruffle, 'Continuous gas carburizing of steel components,' *Metal Treatment*, September 1956.
(2) H. U. Meyer, 'Influence of alloying elements on the case hardenability of carburizing steels,' *Stahl und Eisen*, 1956, 76 (2).
(3) A. E. Gurley and C. R. Hannewald, 'Development and application of the iso-hardness diagram,' *Metal Treating*, May-June, 1956.
(4) F. E. Harris, 'Case Depth,' *Metal Progress*, August 1943.
(5) Private communication.
(6) *Metal Progress*, August 15, 1955, p. 140.

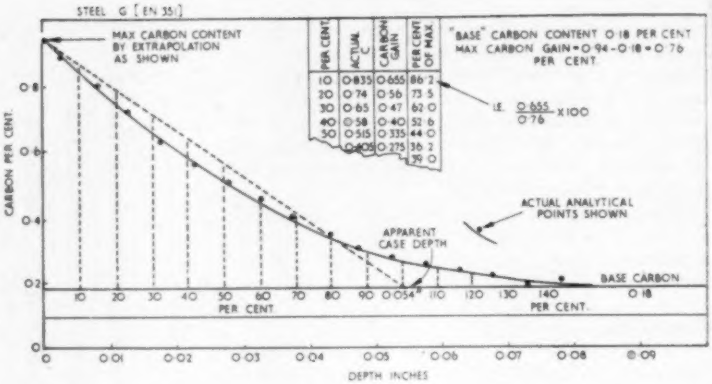
to be continued

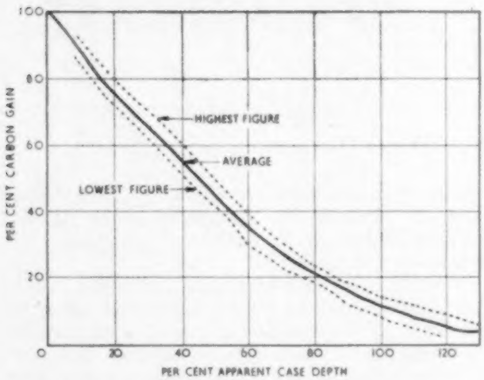
Steel strip equipment for South Africa

The Head Wrightson Machine Co Ltd have received confirmation that they are to receive an order from the South African Iron & Steel Corporation, Pretoria, valued at over £220,000, to cover the supply of a line of equipment for the cutting up of a coil of steel strip $\frac{3}{16}$ in. thick and 54 in. wide into sheets between 4 ft and 20 ft long.

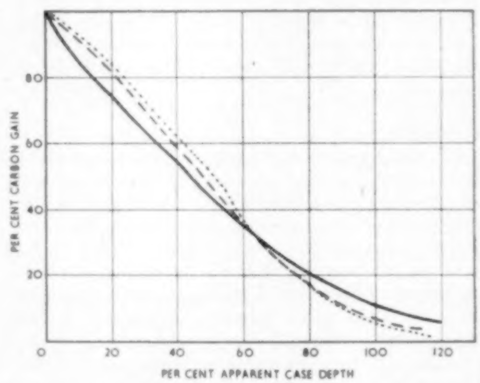
The coils of strip will weigh about 15 tons and will be delivered to the line on a conveyor system. The uncoiling of this heavy gauge material requires very special equipment. After uncoiling, the material is levelled and the edges are trimmed continuously, and the material is automatically measured in thickness, then passed to a 'flying shear' which cuts the strip.

7 *Carbon gradient showing*
(*a*) *Derivation of 'surface carbon'*
(*b*) *Determination of 'apparent case depth'*
(*c*) *Derivation of 'dimensionless' curve*





8 *Carbon gradient 'pattern' for 17 specimens*



9 *Comparison of characteristic carbon gradient patterns*

alloy content and maximum carbon have been made and the results are summarized in Table III to demonstrate the point numerically.

It may be concluded that carbon potential can only be precisely defined if the steel composition is stated, among other conditions, but that variations are not of sufficient magnitude as to cause misgivings about simultaneous treatment of varying specifications. Choice of test-piece material should be made with some care and knowledge of the variation to be expected. Our own original choice of SAE 4620 as standard check material would seem now to have been a good average selection.

(2) *Case depth* Debate on the definition of this term occupies a sizeable percentage of carburizing literature; this article will be long enough without plunging into this well-trodden morass and it will suffice to say that any definition of case depth must, of necessity, be somewhat arbitrary. It is obviously important to know how case depths compare on various compositions carburized together and on this point one could quote very many references and find some odd contrasts.

At this stage, we are concerned only with the basic *chemical* pattern and the discussion here is based solely on the analytically determined composition gradients. The Writer considers that the most satisfactory proposal for comparing 'composition case depth' is that proposed by Harris[4] in one of the earlier of his notable series on this subject. The method employed for this can be explained using fig 7 as an illustration.

The gradient determined analytically is plotted and a curve drawn to follow the points. A straight line is drawn at the level of the core carbon content (0·18% in this case) and the maximum carbon content determined by extrapolation of the curve to the surface. By inspection and trial and error, a straight line is drawn from the maximum carbon content point to intersect the base carbon line in such a way that the area of the triangle thus formed is equal to the area between the experimentally determined carbon curve and the base carbon line.

New thermo-chemical techniques

Part I Bright annealing

P. GALMICHE, Ingénieur-Docteur

In this article, descriptions are given of various new techniques derived from the ONERA process of bright chromizing, which can be carried out by using the same equipment. Part I describes the bright annealing of steels and refractory alloys, while Part II, which will appear in next month's issue, deals with different applications of the hot chromizing process and of reducing atmospheres halogenized 'at equilibrium' in powder metallurgy. Mr Galmiche is with the Office National d'Etudes et de Recherches Aéronautiques (ONERA), France

THE ONERA process of chromium diffusion, in which chromium is diffused into the surface of the pieces being treated by means of chromium fluoride vapour,[1] enables smooth and bright chromium surfaces to be obtained direct on ferrous metals even though the operational temperature may exceed 1,000°C (for periods of treatment of the order of 1—6 h) and though the chromium content of the surfaces of the treated parts may be very high (about 50%).

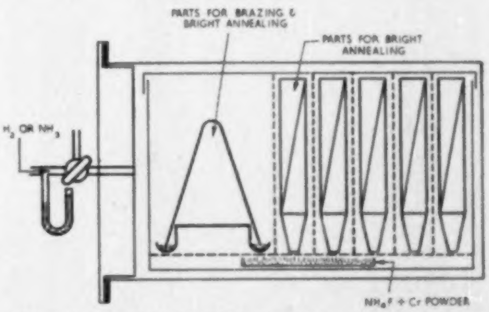
The quality of the surface obtained by chromium diffusion in a fluoride atmosphere is due to the following causes: (*a*) freedom from etching of surface during heating up, owing to the low volatility of fluorides of iron, nickel or cobalt, which form a thin protective coating, this being reduced at treatment temperature (halogens of iron, other than fluoride, are by comparison very volatile); (*b*) diffusion of chromium obtained by dissociation of chromium fluoride fumes without exchange reaction, that is to say without removal of metal from the parts treated; and (*c*) formation in the treatment zone of a reducing atmosphere fluoridized 'at equilibrium,' which is inert as regards the metals under treatment but in which no oxide is stable.

The ONERA process of bright annealing of steel and refractory alloys consists of the use, for annealing, of reducing atmospheres halogenized 'at equilibrium' similar to those which are produced in the ONERA process of bright chromizing. The plant used is also the same.[2]

Bright annealing process

The methods of working are simple. The workpieces are put inside a nearly airtight box in the presence of ammonium fluoride and of chrome or ferro-chrome in powder or granulated form, this being kept from contact with the workpieces by a grid, although some of the ammonium fluoride, on the contrary, can be in contact with the parts. The treatment boxes are heated up in a reducing or neutral atmosphere, *e g* ammonia or hydrogen, at normal or under reduced pressure (fig 1).

On heating up, the ammonium fluoride reacts with the chromium powder and is dissociated, giving rise to the formation of a low-volatile reserve of chromium fluoride together with a mixture of



1 *Installation used for bright annealing and brazing or for impregnation, with bright annealing, of steels and refractory alloys*

Remote control in tube manufacture

A NEW electronic control system is incorporated in the gas-fired, roller hearth annealing furnace which has recently been installed by Birlec Ltd in the new stainless steel mill of Talbot Stead Tube Co Ltd, Walsall. It is used for the heat treating of stainless steel tubes, either on a continuous or batch production basis. Warner electromagnetic brakes and clutches have been used to provide overall remote control.

The furnace, which can turn out 1 ton of steel/h, comprises four sections, a loading table, furnace chamber, spray quench booth, and unloading table. The hearth of each section consists of a series of rollers mounted adjacent to each other and chain driven to enable tubes up to 40 ft long and 8 in. o d to be carried completely through all four sections.

The furnace chamber, which is pressurized, is divided into four zones. By means of specially designed Birlec control valves, the products of combustion form a controlled atmosphere, thus doing away with any supplementary gas plant. This produces a controlled oxidation on the surface of the steel, which has the effect of reducing considerably the pickling time. Temperature controls and pressure controls are by means of Honeywell-Brown pneumatic instruments.

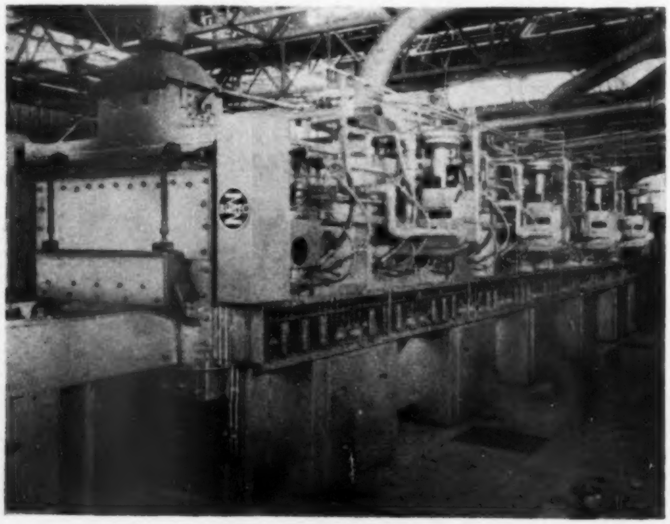
The furnace is controlled from three control desks, situated along the length of the furnace. The main sub-contractor for the control gear was Teledictor Ltd, which was also responsible for the design and construction of the electronic counting equipment and other apparatus.

Six clutches and two brakes are used to allow the whole furnace to be remotely controlled to a given operating sequence. A clutch and brake couples the main 12·5-h p drive motor to the main roller shaft on the loading table, *via* a variable-speed gearbox. This shaft is, in turn, coupled to the roller shaft of the furnace chamber *via* a clutch coupling. A further clutch couples the furnace chamber shaft to the roller shaft in the spray quench section, and this shaft is coupled to the roller shaft on the unloading table.

A 1-h p 1,440-rev/min motor, together with its 120 : 1 reduction gear, is coupled by means of a further clutch to the roller shaft in the furnace chamber. This enables the rollers to be driven backwards and forwards during the heating process to avoid distortion within the furnace. A clutch coupling is fitted with a brake to the output shaft of a 30-h p, 940-rev/min drive motor, this clutch coupling the motor to the roller shaft of the spray quench section so that when engaged, the spray quench rollers are driven at a high speed.

One of the biggest problems which had to be faced on this application was the fact that during the acceleration and deceleration of the rollers in

continued on page 408



Inlet door end of the Birlec roller-hearth annealing furnace at the Walsall works of the Talbot Stead Tube Co

in the case of the protection by chromium diffusion of complex alloys, of which the surfaces would be made too brittle by extensive enrichment in chromium.

On the other hand, one or other of these operations can be associated with a further treatment integrated into the annealing: brazing of assembled parts, of which at least some portion is made of chromium alloy or of chromized elements, leads to particularly spectacular results when the operation is carried out in the atmospheres used for ONERA bright annealing or chromium annealing. We can also mention rediffusion, coupled with de-oxidation and homogenization, of electrolytic or chemical deposits of chromium and nickel on different materials, iron, copper, molybdenum . . . also the halogenized annealing of parts treated with hard chroming, or the bright annealing of the inside of hollow articles obtained by nitric hollowing-out of chromized objects. Finally we can mention the impregnation with metals, such as copper, of sintered products rich in chrome; sintered chrome articles or sintered iron parts with porous chromized finish.

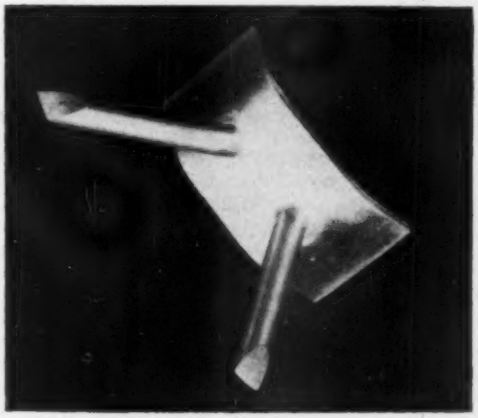
Typical examples of bright annealing

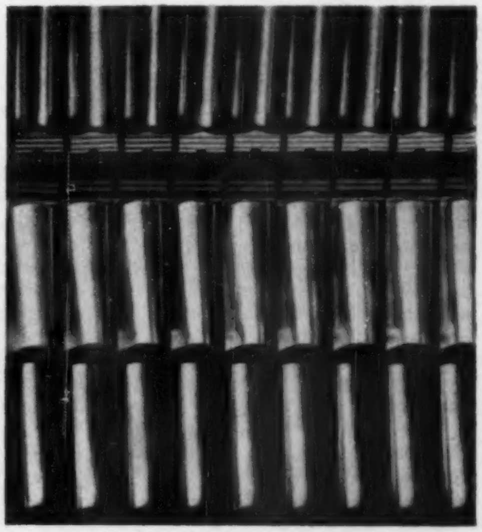
Bright annealing of tubing in 18/8 *steel* The case in question relates to high-temperature annealing (about 1,100°C), without any oxidation, of the outside of tube assemblies, so that there is no danger of contamination in service by oxide particles liable to become detached and so that direct electrolytic polishing of the parts can be done after annealing (passivation treatment). This case is particularly easy to solve and there is only the one problem of sizes of the containers for treatment. When annealing without oxidization or de-oxidizer is applied more particularly to the inside of tubes, certain specific measures must be considered, *e g* the parts can be heated in a salt bath with a halogen-reducing mixture flowing through the inside of the tubes, the halogen acid content of the mixture being progressively reduced (passage of gas at controlled temperature over chromium impregnated with chromium fluoride). Such atmospheres are also suitable for welding or plating chrome alloys.

Protective de-oxidizing annealing for welded assemblies In those cases where refractory alloy parts containing welds have to undergo a relieving annealing treatment at high temperatures (welded tubes, distributor blading, combustion chambers, etc), the use of annealing atmospheres similar to those for bright annealing or chromizing-annealing makes it possible to eliminate oxides which may be present on the inside or outside of the welded areas, and so leads to an improvement in the behaviour of the parts. When treatment is carried out under conditions giving rise to chrome enrichment of the surface areas this allows of an improvement in the behaviour of the parts towards certain reagents, particularly sulphuretted hydrogen in kerosene, or to an increase in resistance to oxidization at high temperatures. Fig 2 shows pieces of tube, with and without original oxidation, which

4 BELOW *Assembly in molybdenum and sheet of chromized iron brazed with* 18/8 *at* 1,400°*C approx*

5 RIGHT *Turbo-reactor blades, skin annealed by bright annealing*





gases, hydrogen, nitrogen, hydrofluoric acid, which drive the air out of the treatment boxes and form a very thin skin of low-volatile fluorides on the surfaces of the workpieces.

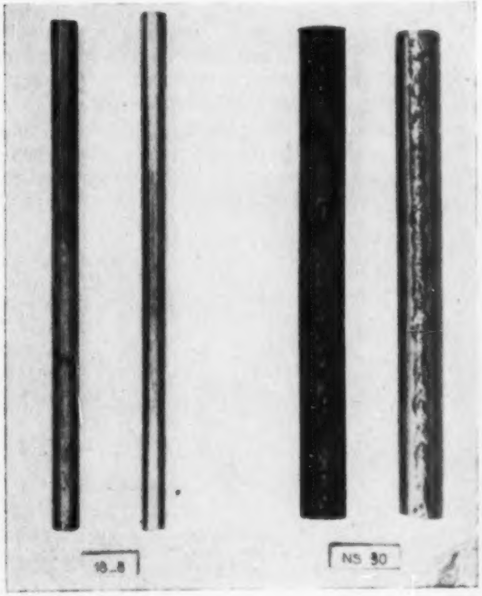
At a high temperature, the protective fluoride skin is reduced along with part of the reserve chromium fluoride, until the point is reached when the concentrations of hydrogen and hydrofluoric acid are equal to the concentration of reducing equilibrium for the working temperature. The composition of the halogen-reducing atmosphere is kept steady, thanks to the presence of the reserve of chromium fluoride, even if small amounts of hydrogen penetrate into the inside of the treatment chamber.

When workpieces with a basis of iron, nickel or cobalt, which can also have high chromium contents, are heated to high temperatures in such atmospheres, they are annealed without any chemical disturbance of the surface areas and, after the boxes have been cooled, the parts are taken out straightaway with a very bright surface provided the treatment temperature has been high enough. With a temperature below 800—900°C, the surfaces of the parts may be coloured owing to the presence of unreduced fluorides.

In those cases where the materials treated are alloys containing elements of which the fluorides are both volatile and very stable (silicon, titanium, etc), these elements are partially eliminated just below the surface. Moreover, when the treated materials are carburized, there may be a slight and regular decarburization of the surface zones owing to the presence of hydrogen in the treatment atmosphere and the absence of oxides on the surface of the parts. Finally, annealing in a halogen gaseous atmosphere when applied to parts already oxidized gives rise to a quantitative de-oxidization of surfaces, the metallic oxides submitted to the action of the fluoride-reducing atmosphere at high temperature being transformed progressively into fluorides, eliminated (silicon, titanium) or reduced (chromium, iron, nickel, cobalt . . .). In this case it is only necessary to see that the temperature of treatment is sufficiently high or that the oxide layer is not too thick. If these conditions are not fulfilled, several successive treatments may be necessary.

Most of the metal which ensures the formation of the reserve of fluoride is recoverable after each operation, only it is essential to add, between two operations, a small amount of acid or neutral ammonium fluoride.

It is possible to carry out an intermediate process between chromium diffusion and bright annealing of refractory alloys by applying a halogen treatment in which the addition of chromium to the parts is limited, for instance, by interposing a grid between the chromium applied and the workpieces under treatment. Such an operation is used, particularly,



2 LEFT *Stainless alloy tubes, bright annealed (untreated samples shown on left in each case)*

3 BELOW *Assembly of refractory alloy parts, Nimonic 75 and HS 31 brazed with de-oxidizing bright annealing (induction heated)*

Some limiting factors in extrusion

S. HIRST, B Sc Tech, A M I Mech E, and D. H. URSELL, B Sc (Eng)

Certain alloys with high strength at their working temperatures pose difficult problems in extrusion. In unlubricated extrusion the conditions involved often cause severe restrictions on extrusion ratio and speed and to widen the field over which the process is possible, lubrication techniques have been evolved. Limitations on extrusion ratio imposed by the dimensions and preheat temperature of the billet for any given press capacity may be expressed in the form of a family of curves on a graph of extrusion ratio against preheat temperature. Extrusion ratio is also restricted by unacceptable temperature rise due to heat input, and this limitation may be expressed in another family of curves on the same graph, thus defining an enclosed area in which extrusion is possible for any given conditions. This basic graph is extended to cover different press capacities, ram speeds, and coefficients of friction: it is shown that it may also be used to predict a phase transformation temperature being reached during extrusion. The relative potentialities of lubricated and unlubricated extrusion are compared. The authors, of the Engineering Section, Research Department, I C I Ltd, Metals Division, presented this paper at the 'Conference on Technology of Engineering Manufacture,' arranged by the Institution of Mechanical Engineers, London, March, 1958

THE PRESENT THEORY of plastic deformation applied to extrusion is limited to the consideration of plane strain for small reductions of idealized material. A theoretical approach to practical extrusion in three dimensions contains so many interdependent variables that a complete mathematical analysis is almost out of the question. Even empirical approaches are difficult because of the practical problems involved in the isolation and measurement of the variables. It is, however, possible to combine the present knowledge, practical and theoretical, with some reasonable assumptions and produce some idea of what is, and is not, possible in the way of extrusion of specified materials. These results are presented in the form of a two-dimensional graph of comparative simplicity. They are satisfactory for normal materials where a standard size of billet may be used over a wide range of extrusion ratios; the final part of the paper shows how a more appropriate selection of billet dimensions may materially assist in the extrusion process.

Notation

- L Billet length.
- D Billet diameter.
- d Mandrel diameter.
- A Area of cross-section of the billet.
- P Ram pressure on the billet at a billet length l, tons/sq in.
- P_L Initial ram pressure on the billet, tons/sq in.
- P Initial ram pressure when $\mu=0$, tons/sq in.
- P_1 Pressure, tons/sq in., required to extrude when the billet is of upset length L_1 in.
- P_2 Pressure, tons/sq in., required to extrude when the billet is of upset length L_2 in.
- Y Deformation stress corresponding to temperature, strain rate and degree of reduction, tons/sq in.
- Y_m Mean deformation stress during extrusion, tons/sq in.
- R Extrusion ratio $= A/a$.
- μ Coefficient of friction between the billet and the container.
- S_g Specific gravity of the billet.
- S_h Specific heat of the billet.
- T_0 Preheat temperature of the billet, °C.
- T Lowest temperature of the melting range of the billet, °C.
- a Area of cross-section of extrusion, sq in.
- x Length of extrusion, in. (including equivalent of that which remains as a discard).
- F Load, tons, required to extrude length L of billet.

have been bright annealed in fluoride atmosphere.

Brazing during bright annealing of assemblies containing elements made of stainless or refractory alloys The use for brazing of atmospheres, as described above for bright annealing or chromizing-annealing of refractory alloys, allows of assemblies being obtained of exceptional quality and with a bright finish on the treated pieces. The surfaces of the parts are indeed quantitatively deoxidized before the substance used for brazing is fully melted, whether it be copper, copper alloys, silver-palladium, silver-manganese . . . In this way, and without the addition of a flux to the brazing material used, we can obtain assemblies of very many chromized materials or made up of items in sintered non-porous chromium, of hard carbides or alloys rich in chrome, 18/8, Nimonic materials, Hastelloy, etc. In addition it is possible to get excellent brazing of very refractory metals or alloys, molybdenum, tungsten, etc, by using chromium alloys as brazing material, melting point 1,150—1,375°C. In this case the fluoride-reducing atmosphere principally acts as a protection for the material used as the brazing agent. This operation can be performed simply by using iron boxes, melting point 1,550°C, heated by the usual methods, or better still by induction heating.

Figs 3 and 4 show, respectively, assemblies brazed in fluorized atmosphere by bright annealing and chromizing-annealing. Fig 3 shows an assembly of refractory alloys HS 31-Nimonic 75 brazed with copper, while fig 4 shows an assembly of molybdenum parts with chromized iron brazed with 18/8 stainless steel.

Skin-annealing of gas-turbine blades[3] The alloys for gas turbines of the 80/20 nickel chrome type hardened with titanium aluminium are very subject to violent and irregular cold working during machining. Parts made of these alloys are therefore generally submitted, after machining, to a short high-temperature annealing (1,080—1,100°C), called 'skin-annealing,' this being done either in a salt bath or in very pure hydrogen. Owing to the very great affinity to oxygen of the various constituent elements of the alloys in question, it is difficult to avoid oxidization of the surface of the components or penetration of parasitic elements during annealing. When treatment is done under the conditions previously described, the parts come out in a very bright condition and definitely not oxidized (fig 5). They can then be polished electrolytically for structure control, without any prior mechanical preparation.

References

(1) P. Galmiche, *Rev de Métallurgie*, July 1954, p 489.
P. Galmiche, *Metal Treatment*, February 1955, p 79.
(2) ONERA, B F 1,074,096—4/2/53.
(3) P. Galmiche, *La Recherche Aéronatique*, July 1957, p 27.
ONERA, B F 1,134,763—13/5/55.

Remote control

concluded from page 404

the individual sections, it was vital to avoid these rollers skidding and, consequently, scoring the tubes. The roller system in each section called for a high starting torque, but once the rollers begin to revolve the driving torque falls to approximately 50% of the starting torque figure.

To provide for this, it was necessary to install an electronic closed loop servo-controlled system for the main drive clutch and the high-speed drive clutch so that at all times the rollers were accelerated and decelerated at a controlled rate to prevent the tube skidding on the rollers. All the other clutches revolve at very slow speeds and are controlled by pre-set potentiometers to give the optimum driving torque and protect the drive chains.

The whole furnace is automatically controlled to provide either continuous, or batch production. During continuous operation, the clutches of each of the four sections are engaged to enable the main clutch to drive the whole furnace so that the tubes are continually passing through the furnace. In batch production, a complete automatic sequence is established in the manner described below.

Tubes which have been placed on the loading table are driven into the furnace chamber by engaging the main drive clutch and also the furnace clutch. When the tubes have moved into the furnace, an electronic counting device causes the drive to be stopped.

An automatic sequence is now started which causes the oscillating drive clutch to be engaged and the motor started. This drive causes the furnace rollers to be turned backwards and forwards a predetermined amount by the reversing of the oscillating motor. During the time that the tubes are in the furnace, a second batch of tubes can be loaded on to the loading table.

When the correct time has elapsed, the operator causes the high-speed clutch to be engaged, together with the furnace and spray quench clutches, so that the tubes are rapidly withdrawn from the furnace and deposited in the quench section. The counting equipment operates as before to stop the drive when the tubes are in the correct position for quenching. The tubes on the loading table can now be driven into the furnace chamber. After quenching the tubes are driven on to the unloading table by means of the high-speed clutch and motor.

Whenever the main clutch or high-speed clutch is engaged, an electronic servo arrangement comes into action, which allows controlled acceleration and deceleration to be achieved irrespective of the load which the clutch has to work against.

conduction depends also on temperature differences. Dies can be cooled by internal water passages and extrusions can be sprayed with coolant. The effect of both devices would be to increase the rate of extrusion possible with the necessary heat dissipation to prevent incipient melting and would bring the incipient melting curve on fig 2 nearer to the isothermal line.

Lubricated extrusion

In the lubricated extrusion process, deformation of the billet is confined to a zone near the die orifice, the billet passing along the container plastically undisturbed until this zone is reached. It has been shown[1] that the pressure required to extrude follows the empirical law

$$P = Y(0{\cdot}47 + 1{\cdot}2 \ln R) \ldots\ldots\ldots\ldots (1)$$

This equation has been derived from experiments on short billets and should be true, therefore, for any length billets when the friction between the container wall and the billet is zero. The frictional effect increases the pressure required to extrude, and a multiplying factor to allow for this increase has been derived mathematically[3] converting equation (1) to

$$P = Y(0{\cdot}47 + 1{\cdot}2 \ln R)e^{4\mu L/(D-d)} \ldots (5)$$

The basic deformation stress Y in general decreases with increase in billet preheat temperature, allowing higher-ratio extrusions to be performed at the higher temperatures for a given specific ram pressure P. The possible extrusion ratio will approach infinity within the melting temperature range. Values of Y for various temperatures may be obtained from lubricated extrusions of the material or by tests of the material carried out on a cam plastometer, a high-speed compression testing machine developed by Orowan and Los.[2]

By substitution of the appropriate values in equation (5) the position and shape of the pressure limitation curves can be calculated and plotted on the temperature-extrusion ratio diagram for given values of the $L/(D-d)$ ratio and for various values of coefficient of friction between the container wall and the billet. When determining these curves from actual extrusions, billets of two different lengths, L_1 and L_2, should be used for each set of conditions, whence μ may be determined by virtue of the fact that the ratio of initial pressures required in the two extrusions is equal to $e^{4\mu(L_1-L_2)/(D-d)}$. If no information is available, then a reasonable value of μ has been found by experience to be $0{\cdot}03$.[4]

The pressure, as given by equation (5), is also a measure of the work done per unit length of billet extruded. If Y_m, the mean value of Y for preheat and final temperatures of extrusion, is substituted in the equation it is possible to calculate the temperature rise of the billet during the operation assuming no heat loss, that is, adiabatic extrusion. The case when the final temperature is raised to the incipient melting point has been derived[5] and is given by

$$\ln R = \frac{(T - T_0)S_g S_h}{4{\cdot}43 Y_m[1 + 2\mu L/(D-d)]} - 0{\cdot}39 \ldots (7)$$

The maximum extrusion ratio which can be used is thus defined in terms of the billet properties and its preheat temperature and will be the limiting case for high-speed extrusion.

In the case of certain alloys, it is known that extrusions are produced with undesirable properties if the deformation is performed above a phase transformation temperature. The extrusion ratio limit can be predicted from equation (7) by substituting the appropriate phase change temperature for T, applying the correct value of Y_m and superimposing the resulting curve on the T/R diagram. Variations of this curve with speed will still apply as for the incipient melting line.

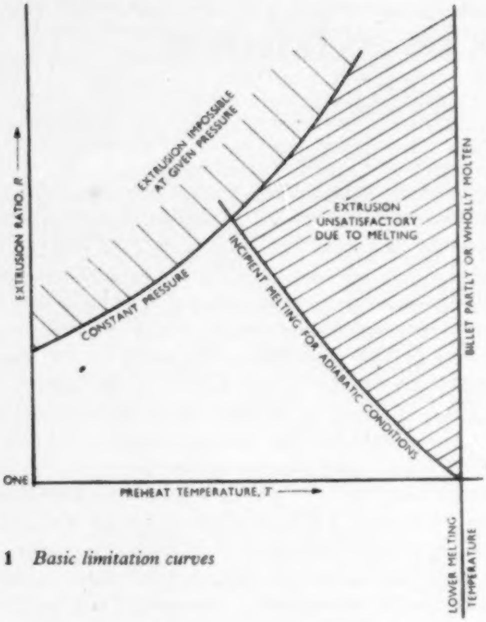
Unlubricated extrusion

Although empirical formulae exist for the die face pressure required to extrude unlubricated billets, no expression for billet length effect, analogous to $e^{4\mu L/(D-d)}$ in lubricated extrusion is available; experience has shown that the pressure required to extrude increases with increase in length of the billet. It is known from experimental observations that shearing takes place throughout the majority of the volume of the billet during the entire extrusion period, necessitating higher pressure than would be needed for a similar lubricated extrusion. This means that, for a given pressure, the extrusion ratio limits are considerably lower than those obtaining in lubricated extrusion. The pressure limitation curve will, however, still have an upward trend with increased preheat temperature and be asymptotic to the vertical within the melting range.

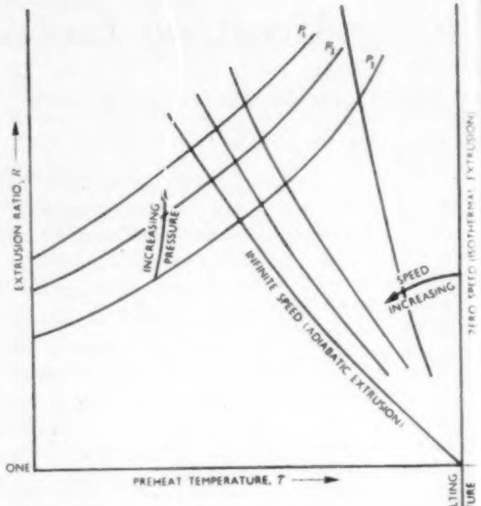
The temperature rise in the unlubricated billet is much greater than that of a corresponding lubricated billet for two reasons. The pressure required, and hence the total work done, is greater and work is done throughout the extrusion on the part of the billet remaining. Therefore, progressively greater heating effect takes place towards the back end of the billet. From this reasoning it is apparent that the temperature limitation curve for unlubricated extrusion will always indicate lower extrusion ratios than its lubricated counterpart, for the same speed.

Comparison with practical results

Fig 3 shows the theoretically developed limitation curves for an aluminium alloy to B S L64 which



1 *Basic limitation curves*



2 *Effect of variations of ram speed and pressure on limitation curves*

Basic limitation curves

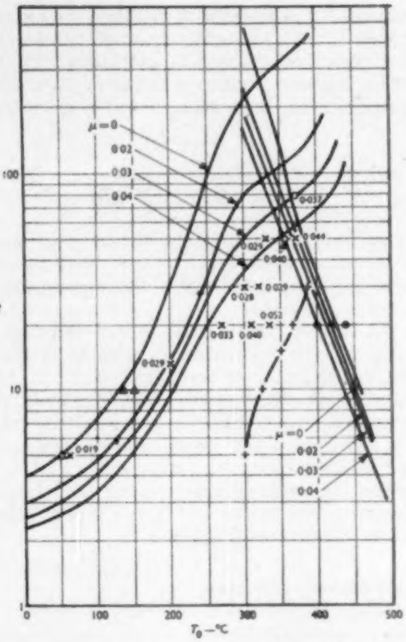
Consider first the basic facts that, for most metals and alloys, the resistance to deformation is reduced by increasing temperature and that any increase in extrusion ratio, under otherwise constant conditions, results in a corresponding increase in the pressure required to extrude a billet; this immediately forms a link between extrusion ratio and preheat temperature of the billet. A line, therefore, exists on the temperature-extrusion ratio graph indicating the maximum extrusion ratio which may be started for any given pressure on the back end of the billet (fig 1). Under practical extrusion conditions peak pressure occurs at the beginning, and extrusion, once commenced, continues. The effect of increasing the pressure on the billet is to raise the pressure limitation curve as shown in fig 2, where $P_1 > P_2 > P_3$.

Under certain conditions the heat generated by the work done on the billet will raise the extrusion temperature to within the melting range of the material. From the basic concepts, the higher the extrusion ratio, the greater will be the amount of work done, and it would be expected, therefore, that the limiting condition, beyond which melting occurs, would be represented on the same temperature-extrusion ratio graph as a curve having a negative slope. Obviously, if the billet is preheated to the temperature at which melting just commences, any work done on it under adiabatic conditions results in melting of the product. Therefore, the curve for infinite speed must emanate from this temperature at an extrusion ratio of unity (fig 1). These two curves drawn on the same graph form, with the axes, a boundary beyond which adiabatic extrusion is either unsatisfactory or impossible, according to the shaded areas indicated in fig 1.

Effect of speed on the incipient melting curve

The increase in temperature of an extrusion is governed by the net heat gain during the forming process, and conditions will always lie somewhere between the extremes of zero heat gain and no heat dissipation. While neither of these extremes can be attained in practice, a very slow extrusion allowing dissipation, through the container and tools, of most of the generated heat will tend towards the former and a very high-speed extrusion, with little time for any heat transfer, will approach the latter condition. From these considerations it is possible to predict the effect of speed on the incipient melting curve which, as indicated by the arrow in fig 2, diverges from the vertical, isothermal condition by an angle increasing with speed to a maximum at the adiabatic curve.

Extrusion speed is normally the main factor governing the rate of heat dissipation to the tools and rate of heat flow forward, in slow extrusion, to the cooler part of the extruded product, but heat



3 *Comparison of theoretical and practical extrusion limitation curves for a maximum pressure of* 50 *tons/sq in. and* $L/(D-d)$ *ratio of* 2·5 *material to B S L*64 (*container diameter* 2¼ *in.*)

× Lubricated extrusion at maximum pressure. Figures indicate coefficients of friction.
Δ Press stalled, lubricated billet.
○ Lubricated extrusion at maximum pressure with incipient melting.
+ Unlubricated extrusion at maximum pressure.
● Unlubricated extrusion with incipient melting.

have been derived from data obtained by plastometer experiments (fig 4). Some practical extrusion results are also shown in fig 3, indicating that the theoretical pressure limitation curves are apparently somewhat high. This divergence of results may be accounted for by the difficulty in selecting the correct Y values for the ram speed in question, the Y values from the plastometer of necessity being quoted against strain rate. To obtain the theoretical curves shown, plastometer results at a strain rate of 30 sec^{-1} have been chosen arbitrarily. Further, practical difficulties have been encountered in obtaining accurate records of the pressure actually applied to the billet during extrusion. In spite of these divergencies, it can be seen that the theoretical curves give a reasonable guide to the range of conditions over which extrusion should be attempted to determine the practical limitation curves.

Although no theoretical prediction of the shape of unlubricated boundary curves is yet possible, a curve is shown in fig 3 indicating the considerable reduction in the scope of unlubricated extrusion, when compared with the lubricated technique, which has been found to exist in practice.

Selection of parameters L, D and d for lubricated extrusion

In the preceding work it has been assumed that the upset dimensions of the billet are fixed by established practice. While this is probably true for the more conventional materials, where many years of experience have determined the optimum bore of the container and a satisfactory length of billet, exceptions arise. Some attractive materials are difficult to extrude, have metallurgical temperature limitations and are sufficiently expensive to justify the volume of the billet being closely governed by the length of product required.

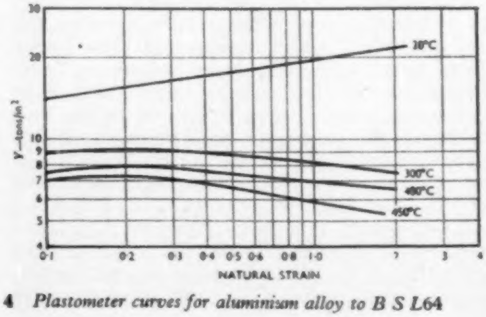
The temperature limits imposed involve extrusion pressures which will exceed the safe working stress of the tools or the full load capacity of the press unless the design of the billet dimensions is carefully considered.

By applying to equation (5) the conditions for the extrusion of a known volume and shape of product, and knowing what value of coefficient of friction may be expected, it is possible to derive the conditions for minimum force required by the ram and for minimum pressure required on the billet. These two conditions are somewhat opposed but reasonable compromises may be effected where both pressure and load are critical. It must be emphasized that the optimum conditions so found will apply only to the volume of billet.

So far, work in this direction has been limited to the extrusion of solid sections but there is little doubt that similar, though more complex, conditions will apply to hollow products.

Equation (5), modified for the extrusion of solid sections only, may be rewritten in the form

$$\frac{P_L}{Y} = 1{\cdot}2 \ln\left(\frac{1{\cdot}162D^2}{a}\right) e^{5\cdot093a\mu x/D^3}$$



4 *Plastometer curves for aluminium alloy to B S L*64

By differentiating this expression with respect to D the condition for a minimum value of P_L/Y, disregarding impossible extremes, is

$$\frac{1}{\ln(1\cdot162D^2/a)} = \frac{7\cdot6395a\mu x}{D^3} \quad\ldots\ldots\ldots(8)$$

with the unimportant proviso that R must exceed $1\cdot32$. The corresponding condition for minimum F/Y is

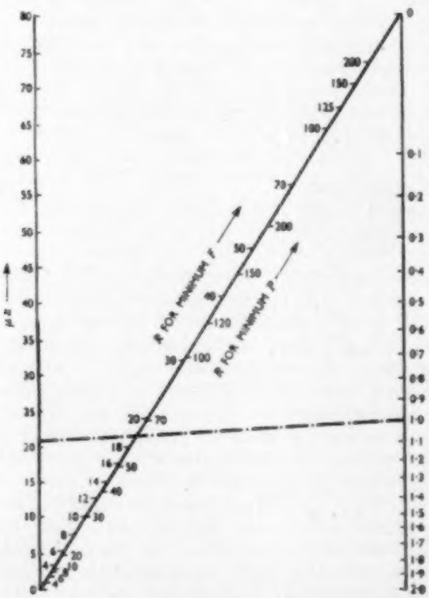
$$\frac{1}{\ln(1\cdot162D^2/a)} = \frac{7\cdot6395a\mu x}{D^3} - 1 \quad\ldots\ldots(9)$$

with R exceeding $1\cdot07$.

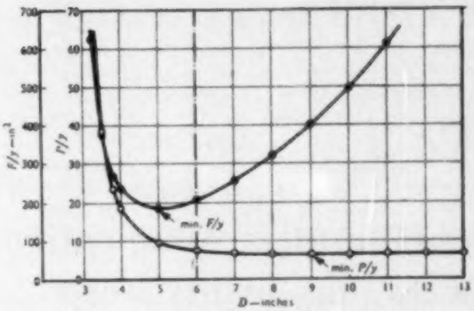
There exists no known complete algebraic solution for equations of the form of (8) and (9) but solutions may be obtained by graphical methods, progressive approximation, or the production of a nomogram. In the last method it is advisable to combine μx as one variable and rearrange the equations (8) and (9) as

$$\frac{R^{3/2}}{\log(1\cdot48R)} - \frac{12\cdot2\mu x}{a^{1/2}} = 0$$

and
$$\frac{R^{3/2}}{\log(1\cdot48R)} - 2\cdot3R^{3/2} - \frac{12\cdot2\mu x}{a^{1/2}} = 0$$



5 *Nomogram for μx, a, and R*



6 *Graphical solution for minimum P/Y and F/Y*

$a = 1$ in.² $\quad$ $\mu x = 21$ in.

◐ $F/Y = (\pi D^2/4)P/Y$. $\quad$ ○ $P/Y = 2\cdot76 \log(1\cdot162D^2)e^{1\cdot07/R}$.

respectively so that the nomogram has a more general application as shown in fig 5.

When considering a compromise on the final selection of container bore care should be taken not to diminish this diameter below that for minimum load. The reason for this may clearly be seen in fig 6 which shows the variation of P_L/Y and F/Y with container diameter for a given product and indicates a very rapid increase in both load and pressure for values of D only slightly below that for the minimum load.

Discussion

The method of calculating pressure and incipient melting limiting curves appears to be reasonably accurate for lubricated extrusions and can give a good guide to optimum preheat temperatures for maximum extrusion speed. Precise operation temperatures would, of course, have to be determined in practice using the theoretical figures as a first approximation. Unlubricated extrusion is not so amenable to theoretical treatment, but the same method of graphical representation can be used to plot practically obtained points from which rational operating conditions can be chosen.

There can be little doubt that lubrication greatly extends the range over which extrusion can be started with a given press capacity and will allow higher extrusion speeds as a consequence of the lower rate of heat input. For a given extrusion ratio the tool loading will also be lower when the extrusion is effectively lubricated, and for many of the 'difficult' new metals this is a serious consideration.

It is of interest to note that in the case of certain metals and alloys having high strength up to incipient melting, and which are therefore difficult to extrude in practice at any reasonable ratio or speed, calculation shows the two limiting curves to cross at a low extrusion ratio. Such alloys are clearly

continued on page 416

N A D F S Spring lectures 1958

No 2

Metallurgical examination of forging-quality steels

Continuing the series of synopses of the N A D F S Spring lectures for younger members of the industry, we reproduce below some of the main points of the second of the 1958 *series given on April* 29, *in which Mr J. D. Bunton, F I M, chief metallurgist of Garringtons Ltd, discussed some of the difficulties of assessing the qualities of steels supplied to the drop forger*

A NOTABLE FEATURE of forging-quality steel, said the lecturer introducing his subject, was its lack of precise definition. There was no clearly defined 'forging' quality. Instead, there were different categories of forging-quality steels from different sources and also sometimes from the same source. The nearest approach one could make to an economic use of these steels was by taking into account, in general terms, the conditions which applied during and subsequent to forging and attempting to ensure that steel was capable of meeting these conditions.

As to what was required to ensure good forgeability, one might say that primarily it was that there should be no defects in the billets or bars being forged which would result in rejection of the forgings. Whether or not a given defect opened up would depend to a great extent on the nature of the forging operation. An upending operation, such as used in the manufacture of a gear blank, would obviously impose greater strain on the metal surface than was the case in making a 'lay-in' forging where the working force was normal to the axis of the steel. Press forging of induction-heated stock was more critical of surface defects than hammer forging of steel heated in oil-fired furnaces. In the former case there was a limited number of blows on steel from which there had been the minimum of metal removed by scaling. In the case of plain carbon steels, the prime quality in terms of surface quality was 'upending quality'; secondly, there was forging quality and then commercial quality. There was no hard and fast dividing line between these qualities, and in certain cases the stipulation of the higher-grade quality was solely an insurance against the cost of rejections.

Surface quality of steels

Difficulties were involved, said Mr Bunton, in assessing the suitability or otherwise of a cast of steel in terms of surface quality. One way would be to remove all the scale and then meticulously to examine each bar or billet, filing each defect to determine its depth. There was neither the time nor the money available to do this. The alternative was to pickle a few samples selected at random from a consignment and examine them in the laboratory. Another set of samples should be selected for an upending test which consisted of heating them to the appropriate forging temperature, upsetting the samples under a hammer to approximately half of their original lengths, and then examining them in the black condition. If the suitability or otherwise of the steel for a particular type of forging was then in doubt, a trial batch of forgings would enable one to reach a decision.

Other factors affecting forgeability were piping, excessive segregation, heavy stringers and corner weakness. Regarding piping and corner weakness, the chances of carrying out an adequate assessment of quality in terms of these defects were no more favourable than in the case of surface quality. Very severe piping might be detected by observation, or be revealed in some of the laboratory samples. If it were suspected in a particular cast, resort could be made to macroexamination or fracturing of bar or billet ends or by sulphur printing.

Heat treatment

Turning to heat treatment, Mr Bunton said that the properties required in a steel to ensure satisfactory results from heat treatment included adequate hardness and adequate mechanical properties, freedom from cracking or excessive distortion. Factors to be considered were: Chemical composition; grain size; hardenability; piping and segregation; and non-metallic inclusions.

Chemical composition. There was an undoubted tendency nowadays for certain large users of drop forgings to attempt to follow American practice in regard to steel specifications and heat treatment, which was to get as much as possible out of the cheapest steel. A difficulty was that tolerances in composition which our British steelmakers demanded sometimes resulted in the steel not being able consistently to meet the properties required from a specified heat treatment.

Also, there was a tendency to forget that there

were other elements in plain carbon steel besides carbon and manganese which determined its reaction to heat treatment. A steel of a certain carbon and manganese content made by the electric-furnace process might have quite a different category of hardenability from another steel of similar carbon and manganese content made by the open-hearth process due to the difference in residual elements between one steel and the other. That was not always fully appreciated and might lead to quite different results from hardening when two casts of different source were used. American steels were predominantly basic open-hearth, whereas nowadays a quite sizeable and increasing proportion of plain carbon steels made in this country were of electric manufacture, in which there was a cumulative increase in residual elements from scrap. One of the most critical heat treatments based on this American practice was induction heating for localized hardening. Using certain British special-applications steels, there should be no difficulty in meeting the required tolerances of induction hardening, but the effects of residual elements often gave results surprisingly different.

Grain size was an important factor in heat treatment in its effect on hardenability and on machinability. A large-grain steel possessed greater hardenability and was therefore more prone to cracking and distortion. Also, more difficulty was experienced in obtaining the necessary impact properties with a large-grain steel.

Normally the usual grain-size test was straightforward, but there was the exceptional occasion when a true assessment might be difficult. Thus, some alloy steels were not always uniformly etched by sodium picrate reagent, with the result that what appeared to be a large grain in a certain area might, in fact, comprise a number of small grains, the boundaries of which had not been etched. Also a peculiar phenomenon sometimes occurred whereby a layer showed large grains not far below the surface of the specimen. At the surface there were fine grains, below which was a large-grain layer, and below this was again a fine-grain structure.

Hardenability, said Mr Bunton, was becoming increasingly important and particularly in components subject to the American procedure of using plain carbon steels for highly-stressed components. Particularly so in the case of induction-hardened components. It was also important in its effect on distortion of gears and other components on which the final machining tolerances were narrow. High hardenability was liable to cause stress cracking or excessive distortion during or immediately after quenching. On the other hand, a low-hardenability steel could fail to give satisfactory core properties following heat treatment. The hardenability tests commonly in use were the Rockwell inch test for plain carbon steels, and the Jominy test for alloy steels.

A useful check on the hardenability was possible by the calculation of the chemistry factor based on the hardenability values of the various elements in the steel, *e g* C, 1,000; Mn, 500; Mo, 1,000; Cr, 400; Ni, 100; Cu, 25.

Segregation or banding was not an uncommon fault and it could lead to trouble in heat treatment. It could also be accentuated by certain forms of heat treatment, and particularly in the case of cyclic annealing. The degree of banding could vary from a comparatively innocuous form to a very severe form where there were alternate layers of martensite and pearlite. The banding or segregation might be of carbon, phosphorus or alloy elements. Excessive segregation would cause not only erratic hardness values, but it might also cause cracking and excessive distortion.

Non-metallic inclusions were liable to cause cracking on quenching, but their most important effects were on machinability.

Machinability

The machinability of drop forgings, said Mr Bunton, was of the greatest importance and also very complex. The metallurgical factors might be classified as follows: (*a*) Hardness; (*b*) grain size; (*c*) non-metallic inclusions; (*d*) segregation (banding; and (*e*) microstructure (*e g* carbide distribution).

Excessively high or low hardness was liable to cause machining difficulties. In the case of low hardness there might be insufficient brittleness to effect chip breaking and clogging of the tool would take place.

Large-grain steel was easier to machine, but gave a poorer finish than fine-grain steel.

Non-metallic inclusions played an important role in machinability, although sulphides were beneficial. Silicates and oxides were harmful, especially in large doses. Very clean electric steel could on occasion be more troublesome than dirtier open-hearth steel due to the lower sulphur content of the former. It was surprising, therefore, that, in view of the importance of non-metallic inclusions in terms of machinability, heat treatment and in service, few steel users appeared to make any serious attempt to define what they wanted in this connection. There were, of course, practical limitations to what the steelmaker could produce in regard to clean steel, but in many cases there was room for improvement.

At Garringtons, said Mr Bunton, they assessed cleanliness by macro-examination of step-turned billets or bars following magnetic crack-detection, and they also used micro-examination. In the latter case the Fox inclusion count was a quick assessment, but did not classify the inclusions; the Jernkontoret count took longer, but was more revealing. The

Operational research in industry

W. E. DUCKWORTH, M A, A I M, A I S

In the leading article of our issue of November, 1957, we appealed to readers for information of any articles explaining in non-specialized language how operational research workers undertook their various tasks. As a result, we have received two such contributions from operational research scientists working in the metallurgical industries. Mr Duckworth, the author of the first of these articles, is a metallurgist who has specialized in operational research methods and is manager of the Operations Research Department of the Glacier Metal Co Ltd. The first part of his article appeared last month and is concluded in this issue. Next month it will be followed by a contribution describing operational research at I C I Metals Ltd

Stock and production control models

Excessive stocks have always been one of industry's main headaches, but this problem is accentuated in present times where the credit squeeze makes capital a scarce commodity, especially for the smaller firm. Many a manager must feel that if he could reduce his stocks he would have more money available for expanding his business.

There are really three problems to be considered. One is to decide what should be the minimum stock level of any component at which a fresh order for that component should be placed. The other two problems are to decide what amount to order when the order is placed, (*a*) when one is purchasing from an outside supplier, (*b*) when one is manufacturing the item oneself.

The problem of minimum safety stock or minimum re-order stock level, whatever one likes to call it, has been tackled in a variety of ways by O-R workers. The problem arises because there is a delay between ordering the goods and receiving them, and one needs a stock to cover sales during this delay. If sales were at a constant and predictable rate and delivery were assured in a certain time, then there would be no difficulty. The re-order stock level would be the exact amount of stock needed to provide for the quantity sold during the delivery period.

It is when both the sales rate and the delivery period vary that the difficulties become acute. If one allowed just enough stock to cover the average rate of sales during the average delivery period, then it is not difficult to see that, because half of the sales rates would be above the average and half of the delivery periods would also be above the average, then in 50% of the cases the above amount of stock would not be sufficient and would be reduced to zero before the order arrived. Very few companies would tolerate such a high occurrence of delays in either providing customers with their demands or supplying other production departments with their requirements.

Thus stocks in excess of what is required on the basis of average sales and average delivery times are carried. The smaller the risk of running out of stock the greater the stock that must be carried. It is possible for any given situation to calculate, using the methods of mathematical statistics, the size of stock to carry for given probabilities of running out of stock. When a manager is presented with a clear indication of what stock he must carry to reduce this risk to 1 in 500 or 1 in 1,000 (probabilities which many stock controllers feel they would like to achieve), he is often able to reconcile himself to a risk level of 1 in 50 in order to adjust his safety stock to a reasonably economic level. This risk level of 1 in 50 can often be more cheerfully accepted when calculations show that even when a stock-out occurs fresh supplies are available within a day or so.

This rationalization of stock levels with commercial risks is usually the first task of an O-R worker in investigating stock problems and the savings which can accrue are often quite substantial because when stock-outs occur in such a system, provided that they happen with the appropriate frequency, they are recognized as one of the expected consequences of the original management decision on stock levels. They do not become an opportunity to shower recriminations on the stock controller who, in the absence of such awareness, would seek protection in ever-increasing stocks.

The second and third problems, those of re-order quantities, are tackled in a somewhat different way. Again two opposing commercial considera-

subject of steel cleanliness was very important to the drop forger, as he encountered rejection of forgings due to dirty steel, although his customer might have made no attempt, in the first place, to define what he wanted in that respect.

Excessive segregation or banding might cause machining difficulties. Sometimes it might be dispersed by hardening and tempering. It was usually accentuated by annealing, and particularly by cyclic annealing. Carbide distribution was also of importance. A lamellar pearlite which might be beneficial for certain machining operations might be harmful for others. The main points to watch in attempting to avoid machining complaints were inclusions and grain size, and it would be to the drop forgers' interest to investigate the possibility of having Standard specifications for inclusion content.

Discussion

It was suggested that the lecturer seemed to deprecate the fact that some steel users tended to follow the American practice of pushing very low-alloy steels to their limits and that users in this country had been far too conservative in their approach to the treatment of steels. Surely steels of rather lower alloy content could be used without detriment so far as structure was concerned, and would have the advantage that an aircraft factory, for instance, could carry a much smaller stock of different alloy steels?

The lecturer remarked that there was much to be said for economizing in alloys, providing one was working on known facts. The problem was that in this country there was an attempt being made to emulate American practices under quite different conditions, and some customers had undertaken jobs of which they had no previous experience in terms of the steel being used. The result was that they were sometimes in danger of saving £10 per ton on the steel, but spending £30-£40 on inspection and rejection.

On the question of specifications, it was asked whether perhaps the industry was not blindly following a tensile-strength requirement of material with a complete lack of consideration of far more important properties, such as fatigue, notch-sensitivity and other factors, and how much it was felt that the more important considerations of functional purpose of a forging was affected by grain flow, etc, as distinct from surface defects and grain size.

Mr Bunton, in the course of his reply, said that quite recently he had come across certain jobs which were giving trouble in service because hardenability was not covered in the specification. The steel was entirely satisfactory so far as the nominal specification was concerned, but, because the hardenability was higher than it should be, it appeared to be giving rise to high-tensile stresses in the surface, which might be giving rise to fatigue failure. But on the whole, however, he considered that in 99 cases out of 100 the present methods of testing and of specification were correct.

Mr Bunton was asked if it was not a fact that on the hammer one could get flashing-up in areas of overheating that could be absent on a press. He replied that in using a press, particularly after induction heating, the steel had to be better than it was when using a hammer after heating in an oil-fired furnace. There was, of course, the percussion heating effect of the hammer, and if one was running too near the maximum permissible temperature overheating was possible. In that case, if the stock was not heated too near to the maximum permissible temperature, the percussion heat need not be taken into account. So far as the properties of a forging were concerned press forging gave a better job, but the steel also had to be better.

Regarding the supply of fine-grain material, a member of the audience pointed out that it quite often happened that the steel manufacturer, by ensuring one property, did so at the expense of another. It was well known that fine-grain steel was usually dirty, because the standard method of grain refining was by additions of aluminium, which produced probably the most undesirable form of inclusion. There was no other way to obtain a fine-grain size, and that was typical of many of the problems which had to be faced.

Limiting factors in extrusion

concluded from page 413

more likely to extrude if lubricated because of the lower heat input, but graphs such as fig 3 can show the advantages of using high billet pressures to overcome incipient melting difficulties.

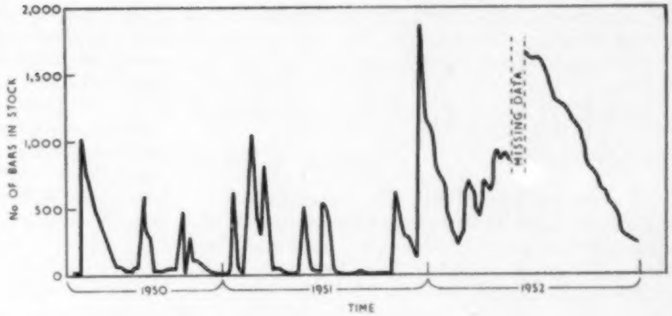
Theoretical calculations of billet dimensions are particularly useful when designing new plant or selecting the appropriate plant for materials where experience is lacking. Reference to fig 5 enables the container diameter, length, and the applied pressure to be chosen on a sound basis.

Acknowledgements

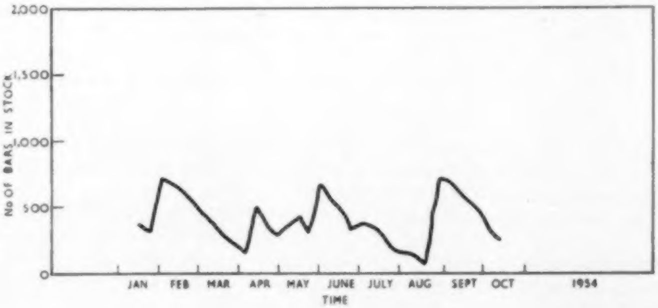
The authors express their thanks to Imperial Chemical Industries Ltd, Metals Division, for permission to publish this work and to Dr. T. A. J. Lamb who participated in much helpful discussion.

References

(1) W. Johnson, 1955, B I S R A Report No. MW/E/55/54.
(2) E. Orowan and Los, 1950, B I S R A Restricted Report No. MW/F/22/50.
(3) (4) (5) The mathematical derivations of these equations were given by the authors as Appendices.



8 RIGHT *Actual variation in stock level of* 1-in. *solid bronze bars, April* 1950–*December* 1952. (*Before O-R investigation*)



9 LEFT *Actual variation in stock level of* 1-in. *solid bronze bars, January to October* 1954. (*After O-R Scheme*)

economically acceptable. This assessment is based upon a whole host of intangible factors which no O-R investigation can hope to tease out. The assessment will vary according to the economy not only of the firm in question but also of the country as a whole. When this assessment can be used to select one from a variety of schemes which the O-R man presents and each of which is internally consistent, then the most fruitful and effective combination of intuitive and scientific insight has resulted. The manager knows at what level he wants his company or departments to operate. The O-R man can ensure that it operates at that level consistently, and most people familiar with existing stock and production control schemes know that the bugbear is their inconsistency. Stocks of one part can be skyrocketing while panic measures are resorted to to obtain enough supplies of another part.

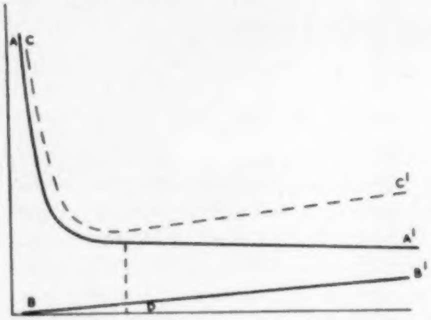
Stock and production control problems are among the most complex to be tackled by O-R techniques and, as a result, progress is slow. Very few O-R-designed schemes are in operation in this country, although many are under investigation. One of the difficulties is that the amount of information required to establish a scheme, operate it and control it is rather high because the relevant parameters are often changing. This problem has been tackled in a very vigorous manner[14] by means of massed batteries of statistical control charts and, although the scheme appears very unwieldy to an outside observer, it has resulted in a marked improvement in the meeting of delivery dates.

A somewhat similar technique was investigated at Glacier some years ago and, although the massed battery of control charts was ruled out as being too expensive, the principles of the scheme were accepted by the person responsible for the stocks of the particular product and he applied them without the refinement of charting. The results can be seen in figs 8 and 9.

It is a very good feature of O-R work that the investigations need not be carried through to conclusions before the results are applied. O-R naturally involves much discussion with managers, many of whom contribute a lot to the success of the O-R, and are enterprising enough to apply the emerging principles in crude form to gain immediate benefit without waiting for the full and refined study to be completed.

Decision functions and game theory

The art of decision making is a very complicated one and it is in essence the true art of management. In industry one is paid for making decisions, so it is natural that O-R workers should study the process and assess how it may be improved. Two



7 *Graphical representation of two factors influencing the item cost in the order problem*

tions are weighed against each other, but this time probability does not enter into the calculation. The inherent variability of the system has already been taken care of in the chosen value of minimum stock level. The two considerations are, first, the fact that one usually obtains the parts at a decreasing cost per item as the order size increases and, secondly, the fact that the greater the order size the longer the parts remain in stock before being sold, and hence the greater the storage and investment cost per item. These two factors, the one decreasing the item cost, the other increasing it, can be represented graphically as in fig 7.

Curve A A′ is the curve showing how unit cost or price decreases with order quantity; the straight line B B′ shows how unit storage and investment cost increases with order quantity. The dotted curve C C′ is the sum of A A′ and B B′ and represents the change in the total cost per item with order quantity. It is seen that there is a minimum total cost per item at order quantity D and this, in simple situations, is the quantity which should be ordered.

The qualification 'simple situations' is necessary for the following reason. When the point D is calculated mathematically it is found that this order quantity is equal to a constant, which depends on manufacturing and storage costs, multiplied by the square root of the rate of sales. If this calculation is used to decide upon the order quantities of several products manufactured on the same plant, then each will be ordered in proportion to the square root of its own sales rate. However, each product will continue to be sold in direct proportion to its own sales rate. There will thus be a lack of balance between the order quantities of these different products and their rates of sale. This will not matter if the several articles represent only a small proportion of the plant's output, because then they will not get in each other's way. But if they do account for the bulk of the plant capacity, then there will be occasions when two separate articles will need to be produced at the same time. This is impossible, of course, and the makeshifts which will have to be introduced will cause serious departures from the optimum policy.

The simple situations in which quantity D should be ordered are, therefore, those in which the items purchased from outside suppliers or ordered from another production department represent only a small proportion of the relevant productive capacity. Just how small this proportion needs to be in given circumstances is not yet known—it is under investigation by the author's team—and it is a weakness of much of the published work[12] on this subject that the failings of the formula for calculating the optimum re-order quantity have not been sufficiently recognized. This illustrates that O-R workers themselves are far from infallible.

Where it is not possible to order products independently of one another with safety the concept of the production cycle is used. Within a given production cycle each product is ordered in an amount proportional to its rate of sale—which is clearly sensible—and it is the length of the production cycle which is optimized. Various mathematical techniques exist for doing this based on the same principle as that used in the simple formula—balancing the decreasing unit costs with larger cycle time against the increasing investment costs of larger quantities. One successful application has been programmed for an electronic computer and is now in regular operation.[13]

As with most of the mathematical formulae used in operational research the actual numbers to use in the formula are hard to obtain accurately. What, for instance, is the cost of holding items in stock ? The actual charge for physically containing the material can probably be calculated readily enough, but what about the investment charge ? Does one use the Bank Rate ? The Share dividend ? What one could earn by using the money elsewhere ? These figures vary widely and one's optimum scheme can vary also within wide limits according to the figures one adopts.

The solution to this difficulty illustrates an aspect of operational research that possibly is not clearly understood. It is not the object of O-R to usurp the decision-making function of a manager, it is to give it a greater scientific precision, a cutting edge. Thus, instead of worrying which value to place on investment interest or chivvying accountants to provide it, the O-R worker calculates several schemes based on different values of investment interest, etc., and presents these to the manager who has to make the decision.

This manager has his own intuitive assessment of the level of investment which the company can carry and of the production cycle lengths which are

Nos 1, 2, 3 and 4 are four choices placed before a manager; A, B, C and D are four possible outcomes which may occur once a choice has been made. The negative numbers in the squares indicate the losses which may arise from each choice in the event of a certain outcome. Thus, if choice 3 is made and the outcome is B, then a maximum loss of 900 could occur. Some of the values are positive, indicating that with the particular combination of events a profit would be made.

What choice would you make—1, 2, 3 or 4 ? The minimax rule says choice 2 because then the maximum loss 300 in the worst outcome D is lower than the maximum loss in the worst outcome with any other choice whose maximum losses are respectively 800, 900 and 500. Thus, by choosing 2, one has minimized one's maximum loss—hence the term ' minimax.'

You may prefer other rules. You may prefer choice 4 because it gives the highest profit (+700) or because it gives the highest average profit. In practice, however, it is found that managers tend to be pessimistic in their judgments and to safeguard themselves and their companies' assets by choosing the alternatives which lose least if they go wrong, rather than profit most if they go right.[17] To be aware of this and also to assess the probabilities of the various outcomes, which have been excluded from Table II for the sake of simplicity, can often be a valuable exercise and can aid the executive in reaching an appropriate decision.

Game theory is an extension of decision theory where, instead of one's choice of action being conditional on the possibilities of several outcomes, they are determined by the result of the opponent's action in reply.

Consider Table III.

TABLE III

	A	B	C	D
1	4	2	4	3
2	2	-4	2	0
3	3	-6	4	2
4	4	-2	2	1

Nos 1, 2, 3 and 4 are the possible strategies, say, of oneself, and A, B, C and D are the possible strategies of one's opponent. How should one play the game ? If one plays strategy 2 one gains 2 points if the opponent plays A or C, but loses 4 if he plays B. One cannot be sure when one plays 2 what one's opponent is going to do in reply.

Here again a minimax rule exists. If one plays strategy 1, one wins at least 2. If the opponent plays B, he does not lose more than 2. Thus one's own minimum gain is the same as the opponent's maximum loss. The square 1B is unique in this respect and this is called the saddle point or the solution of the game. If the game were played out in practice it would be found that the strategies would converge to this point, because if one plays strategy 1, the opponent can do no better than play strategy B.

It is the merit of the game theory approach that it has shown that all games have this kind of saddle point, although they are far more complex than in the above example and consist of a mixture of strategies. The principle is the same, however. In a given situation one can choose a strategy or mixture of strategies such that whatever the opponent does he cannot do better than a certain result which is calculable in advance. The advantage of this foreknowledge in competitive situations is obvious.

Once again, as in decision theory, the evaluation of all the components of the game is a difficult task, but it has been done with success in simple situations in the author's company and the clarification it gives as to the correct choice of action is very illuminating.

The theory is in a very early stage, of course, but with greater experience and more knowledge of how to evaluate the relevant parameters it can make a contributon to the manager's ability for decision making. A most illuminating study of business games has recently been carried out in the United States.[18]

Cybernetics

Most industrial operations involve control and regulation and substantial strides have been made in recent years in understanding the nature of complex control systems. The approach has been to combine the mechanistic outlook of the electronics expert and servo-mechanism engineer with the organic knowledge of the biologist and neurologist in the new science of cybernetics. This may be defined as the study of control systems in man and machine and the relationship between them. From the work of cyberneticians two important control principles have emerged: one is that of error-actuated feedback, the other is homeostasis.

The feedback principle can best be illustrated in one of its simplest forms, that of driving a car. The driver aims at a certain position on the road and checks after a few seconds if that position has been attained. If the difference between the desired position and the actual position is great enough an appropriate adjustment is made to the steering wheel, the new position is checked after a further few seconds and the cycle is repeated. The significance of this operation is that the error

techniques are being examined: decision functions and game theory.

The general statement of a decision function is as follows:

Expected utility = Probability of success × value of success
− Probability of failure × cost of failure.

An illustration of this function is the tossing of pennies for reward. Suppose one is playing a game with an opponent. If the penny comes down heads it is yours, if tails it is his. In this game

Probability of success	=	$\frac{1}{2}$
Value of success	=	1d.
Probability of failure	=	$\frac{1}{2}$
Cost of failure	=	1d.

Therefore

$$\text{Expected utility} = \tfrac{1}{2} \times 1\text{d.} - \tfrac{1}{2} \times 1\text{d.} = 0$$

One would not expect to gain or lose much from joining such a game and one certainly would not do so with any expectation of profit. This result is in accord with experience.

Another illustration is the football pool situation. The probability of winning £75,000 on the eight results with a single stake is 1/73,000,000. The stake, which one loses anyway, is 1s.

Therefore

$$\text{Expected utility} = 1/73{,}000{,}000 \times £75{,}000 \quad - 1\text{s.}$$

This is very nearly equal to −1s. and is in accordance with the general knowledge that one expects to lose one's first stake in a football pool.

A more general treatment of the football pool case along the lines indicated above would show that the expected utility is always negative and is cumulatively so for a man's lifetime. This is not invalidated by the fact that some people win, because this situation is a closed one, *i e* a certain amount of money *must* be won. For the great majority of people, however, the utility, as well as the expected utility, is negative.

Where one is comparing two situations and deciding whether to decide between them the expected utility is maximized, and the actual value may not be important. For instance, if one is compelled to gamble, the tossing pennies situation is more attractive than the football pool one because, although the expected utility for tossing pennies is zero, it is nevertheless greater than that for football pools. This may explain why most people do not mind mild gambling when playing cards, although they would refuse to join a football pool syndicate. Social pressure plays a part here, of course, but even so the comparison is probably valid. Professional gamblers certainly do not make their living from football pools but gamble in situations analogous to the tossing pennies game. They usually contrive to sway the odds in their favour so that the expected utility is positive.

It therefore seems that this type of decision function gives results in accordance with reality. There is one class of exceptions, however. If one had to send £5 by post one would be faced with the decision whether or not to register this amount. Here the successful decision would be a loss of the £5 if one did register it. Therefore the equation is as follows:

$$\text{Expected utility} = \frac{1}{50{,}000} \times £5 \quad - 1\text{s.}$$

where $\frac{1}{50{,}000}$ is the G P O figure for the proportion of lost letters and 1s. is the cost of registration. This expected utility is negative, yet in many cases one decides to register. Why ?

The reason is that a certain delay ensues between posting the £5 and hearing that it has arrived safely. During this time one may be anxious about the fate of the money. Registration provides a way out of the anxiety so in effect one ascribes a value to one's 'peace of mind' and turns the expected utility from negative to positive by so doing.

The setting up of a decision function in a given situation therefore requires the evaluation of the probabilities of certain events and the values and costs associated with them together with assessment of such factors as peace of mind. This is not an easy matter, of course, and very few decisions in industry have been taken on the findings of a decision function. Nevertheless, the exercise is a useful one because it sharpens the executive's perception of the risks he may be running in preparing certain choices and the consequences he may have to face if those choices are the wrong ones.

Many rules have been postulated by mathematicians for making choices in these situations and experience suggests that the one most commonly used, albeit intuitively, by managers is the 'minimax' principle (Table II).

TABLE II *The 'minimax' principle*

	Outcome			
Choice	A	B	C	D
1	−500	+300	+600	−800
2	+400	+200	−100	−300
3	−600	−900	+200	+500
4	−500	+400	+700	−200

weaknesses or speeding up the exercises to the limits of the pupil's capacity.

That these machines will come there is no doubt. They will have many properties which are very desirable in control systems—continuous feedback, rapid response, an ability to recognize patterns better than do human beings, the capacity to explore numerous alternatives without exhaustion and so on. Before the machines are available, however, there is a lot that the O-R worker can do in applying the same principles on an organizational basis so that industry can make much more effective use of the control information it has and be encouraged to obtain further information where it is economically advantageous to do so.

Other O-R functions

This paper has so far dealt with eight specific operational research techniques and their particular application in a medium-sized company. These techniques do not, of course, represent the limit of an O-R team's capabilities. Many of the problems which harass industrial managers because they cut across the work of several specialities can be tackled by an O-R group, especially if it includes, albeit temporarily, members of each speciality.

In the author's company a comprehensive survey of the relationship between selling prices and manufacturing costs is under way. This survey is guided by the managing director acting through the programming division manager and involves accountants, production engineers and salesmen. The O-R team acts as the catalyst which ensures that the work has a continuity which would be difficult to achieve otherwise in view of the other commitments of the above personnel. This survey aims at solving yet another of the perpetual problems of industry—how to arrive at a selling price which is acceptable to the market and gives due weight to all the considerations other than manufacturing cost which the market takes into account, and at the same time provide accountants with adequate cost data for control purposes and provide production engineers with reliable cost information for the purpose of taking their engineering decisions.

An important aspect to emphasize in O-R work is that, although it often cuts across the work of several departments, it is in no way set above these departments. It does not exist to judge, but to discover. The decisions arising from O-R investigations must always be made by the managers requesting the investigations.

Very often the problems which arise in a manager's department could be tackled by the manager himself if he had more time, and several of the author's investigations have closely followed the lines laid down by the requesting manager, because these were the best ones to follow.

Conclusion

It is the author's hope that this paper has given some notion of the scope of operational-research work, sketched an indication of its achievements in a single company and described some idea of its potentialities for the future. The article was written because of the complaint that not enough is heard of the results of O-R work. This complaint is well-founded for two reasons. One is because so much O-R work is concerned with a company's commercial activity that security prohibits its publication. The second is because O-R work is, by its very nature, team work, not only within the O-R group but between the O-R group and many other people in the company. The ideas which are successful in O-R work are not exclusively those of the O-R men. Many come from the other people in the investigation who must hand them to the O-R group because of lack of time to develop them themselves. Therefore to publicize too much the O-R successes would be invidious. Much of the credit belongs to the managers, who would naturally resent the implication that O-R had successfully told them how to solve their problem.

The material in this paper owes much to many such men at Glacier Metal Co Ltd with whom the author is fortunate to work and, if this article has succeeded in persuading anyone that an O-R team is a good thing to have in one's business, then to them much credit is due.

References

(1) C. W. Churchman, R. L. Ackoff and E. L. Arnoff, 'Introduction to Operations Research.' Wiley, 1957.
(2) P. G. Forrester and W. E. Duckworth, *Lub. Engrg*, January 1957, p 38.
(3) W. E. Duckworth and P. G. Forrester, 'Wear of Lubricated Bearing Materials,' International Conference on Lubrication and Wear, London, 1957.
(4) N. B. Rutherford, *J Inst Metals*, 1952, **82**.
(5) M. Whyte, *Ibid*, 1954, **84**.
(6) P. G. Forrester and W. E. Duckworth, 'Properties and Testing of Sintered Copper-Lead Bearing Materials,' Symposium on Powder Metallurgy, 1954, p 219.
(7) A. R. Martin, *J Inst Metals*, 1956-57, **86**.
(8) L. A. Deaville, *Foundry Trade J*, January 9, 1958, **104**.
(9) G. Morton and E. Kay, *Metalworking Production*, December 23, 1955, **99**.
(10) F. D. Robinson and W. E. Duckworth, 'An Application of Queueing Theory to the Speed of Estimating,' First International Conference on Operational Research, 1957.
(11) L. H. C. Tippett, *Time & Motion Study*, May, 1953.
(12) T. M. Whitin, 'The Theory of Inventory Management,' 2nd edn. Princeton, 1957.
(13) A. Battersby, 'Production Control in a Chemical Factory,' Royal Statistical Society Conference on Production Control, London, December 13, 1957.
(14) Stafford Beer, United Steel Co, private communication.
(15) Ross Ashby, 'Introduction to Cybernetics.' Chapman & Hall, 1957.
(16) S A K I. Produced by Solartron Electronic Group, Thames Ditton.
(17) E. S. Mills, 'The Theory of Inventory Decisions,' *Econometrica*, April, 1957, **25** (2), 222.
(18) R. Bellman *et al*, 'On the Construction of a Multi-Stage Multi-person Business Game,' *Operations Research*, August, 1957, **5**, 469.
Two useful new books in operational research are
(19) P. M. Morse, 'Queues, Inventories and Maintenance.' Wiley, 1958.
(20) J. F. Magee, 'Production Planning and Inventory Control. McGraw Hill, 1958.

between the actual and required position is fed back to the driver and action is taken on the size of the error. This is what is meant by error-actuated feedback.

The inexperienced driver, determined to permit himself the minimum amount of wander, will take corrective action on the smallest observed deviation and will make the amount of correction equal to the error. Thus the tyro's steering wheel is continually a-wobble and, as is well known, the result of his efforts is to wander about the road far more than a skilled man.

The experienced driver knows firstly that certain errors in position are quite random and are accidental ones due to variations in road contour or other chance causes and might well be self-corrected at the next hump. These deviations he ignores and thus steers a smoother course than the learner. Secondly he knows that, when a deviation is serious enough to take into account, the correction he makes should be somewhat less than the error to avoid the risk of over-correction. He thus gradually restores the vehicle on to its original course. The dangers of making the feedback equal to the error are well illustrated in temperature controllers which exhibit the familiar phenomenon of ' hunting.'

Homeostasis is the property which all living organisms have of adjusting their metabolism to changing environmental conditions so that certain essential parameters remain constant. The blood temperature of a healthy reader of this article stays constant at 98.4°C. whether he be reading it in tropical humidity or sub-zero frost. The means by which this is done are an object-lesson to any control engineer.

The principle is clearly an important one for industry. The environment of many industrial processes is continually changing. The raw materials vary, the process conditions change and the quality of the operating workers may deteriorate. If nothing else alters the plant itself is ageing and this can cause changes in the quality of the product. Few readers of this article will not have experienced the sudden appearance of new and complex problems on old established processes. These are just symptoms of changes in the process which were not detected and rectified by subtle homeostatic procedures but were allowed to accumulate until their presence could no longer be ignored. The cybernetic approach is to accept that conditions are always changing, to treat the system under observation as a *living* thing with many of the biological and especially neurological properties of living things and so learn to apply the subtle techniques for control and evolution which Nature has used for so long.

The application of error-actuated feedback and homeostasis to industrial operations is clearly a difficult job. The manager of a process is not driving a car, able to see the road ahead, he is in the position a car driver would be in if he only had a glimpse of the road five miles back every few minutes or so. The analogy cannot be stretched too far, obviously, but more operational research will have to be carried out before these principles can be applied to the management function.

The approach is twofold. One way is to build the feedback and homeostasis into the organizational structure so that the appropriate observations are made and the corrections introduced by a human agency. The other is to design process machines which can do the job.

The first method offers more scope for advance on a short-term basis and one process at Glacier is operating on these principles. Observations are taken on a comprehensive scale and with sufficient frequency to enable any significant process changes to be detected. The limits within which the plant personnel can make changes themselves are clearly laid down, but in such a way as not to inhibit development. When changes of a certain magnitude occur then outside technical help must be invoked. In this way adequate feedback at all levels of the process operation is ensured and the homeostatic experience of the plant operators with their knowledge of initimate detail and that of the technicians with their specialist training is utilized to the full.

Another company[14] has also inaugurated a cybernetic scheme based on organization structure and this, too, requires the collection and constant analysis of a large amount of information. Industry tends to fight shy of schemes which require a large amount of information, because data collecting can be very expensive. It should be noted, however, that the adequacy of a control system depends upon the amount of information contained in it. To confirm this, see how accurately you can drive a car by only looking at the road every two minutes. In many cases it may be more expensive *not* to have the information than to collect it.

The second method of advance, that of designing a machine, may overcome the problem of providing information and analysing it, because this will very largely be done by the machine itself at little or no extra cost. The design and manufacture of such a machine will, of course, be a very comprehensive task and one which is at present only being tackled specifically by one industrial group[14] in this country.

That such machines can exist has been demonstrated theoretically[15] and a machine that exhibits a lot of the necessary properties is one now being produced for teaching teleprinter operations.[16] The machine sets the exercises for the pupil and adjusts itself to the pupil's characteristics in a cybernetic manner, concentrating on the learner's

Series on heat treatment

Developments in surface hardening

E. MITCHELL, F I M, A C T (Birm)

In this lecture, given to the Wolverhampton and Staffordshire College of Technology, the author considers the fundamental principles of surface treatment of steel parts, which may be carried out either by altering the chemical composition of the surface, or by localized heating and cooling, giving an altered metallurgical structure. Mr Mitchell is heat-treatment and development engineer at Joseph Lucas Ltd

PROBABLY THE MOST IMPORTANT BRANCH of heat treatment is that concerned with the intentional alteration of the outer layers to provide steel parts with a hard wear-resisting surface while retaining a tough interior. There are two ways of doing this: (1) Use of methods by which the chemical composition of the outer layer of the steel is altered; (2) use of methods in which the surface is hardened by rapid localized heating followed by quenching. It is quite likely that these methods embrace at least 50% of the total heat treatment in this country.

In the first group there are a variety of processes being used, all of which involve chemical reactions at the surface. Carbon and nitrogen are the principal elements used, and the effects are governed by the composition of the steel, the condition of the medium in contact with it and the temperature and duration of contact. Additions of these elements can be made by solid, liquid or gaseous techniques and when thinking of development in this field it is well to bear in mind the features which are important and consider how these have influenced recent happenings. It is convenient to consider the first group in sub-divisions which involve: (*a*) Addition of carbon, (*b*) addition of nitrogen, and (*c*) addition of both carbon and nitrogen.

Addition of carbon

Perhaps the oldest and best known surface-hardening method is that of carburizing. Carbon can be added through the medium of a solid, a liquid, or a gas, the active constituents being carbon monoxide and methane. The important features to be considered are the carbon gradient at the surface, the avoidance of carbide networks, uniformity of case depth in a batch of workpieces and the prevention of distortion. At this stage it is useful to sub-divide the methods of adding carbon and to look at the improvements which have taken place.

Pack carburizing This is the oldest and probably the dirtiest of the carburizing methods, using charcoal with a suitable energizer such as barium or sodium carbonate. It is still in extensive use particularly where short runs or parts of various sizes have to be dealt with. The principal disadvantages of pack carburizing are that it is dirty, it is difficult to control the carbon gradient, and it is slow and involves the heating of large masses of carburizing compound and pots.

Some developments have taken place in an effort to obtain a carburized case with a suitable carbon concentration. These include the control of energizer content in carburizing compound and the use of inhibiting agents[1] in order to slow down the action of a normally vigorous carburizing material. In this respect compounds with energizer contents of 1% sodium carbonate have been proposed as distinct from the rather more usual but stronger compounds with 5-10% sodium or barium carbonate additions. The weaker compounds, particularly with the highly alloyed carburizing steels, give carburized cases of eutectoid composition free from carbide networks. Figs 1 and 2 illustrate the effect of carburizing compound composition on surface carbon. The use of inhibitors such as ferro-silicon, and nickel or chromium chloride has not gained much favour and it has been said that ill-chosen use of these substances may well cause pitting of the article being carburized.

To provide cleaner handling of both work-pieces and compound a number of compound handling devices have been developed. A typical example is given in fig 3 which shows a vacuum separation device for screening compound and re-

Automatic forging press

A FULLY-AUTOMATIC forging press has been developed by the Erie Foundry Company, Erie, Pennsylvania. The 2,500-ton automated press is designed for high production forging of parts such as connecting rods, gear blanks, automotive and tractor valves, stem pinions, ring gears, track links, and wheel hubs. For the past year it has been tested with a set of dies owned by a major farm machinery producer for production of crawler track links. The new press will produce from two to three times the number of forgings that the most productive hand-operated presses have forged, per unit of time.

Depending on the part to be forged, the automatic press, with one man to oversee operation, will replace a line of two or three presses, each manned by two men—a heater and an operator.

Another advantage of the new press lies in its ability to trim as well as forge, so that two or three trimming presses and their operators may also be eliminated if the press is to handle trimming.

Operation of the press

The operation requires three stations: one station to pick up the blank, a second station to semi-forge the part, and a third station to finish the forging. A fourth station, for trimming, may be added if desired.

A conveyor delivers the hot bar from the furnace through the left window of the forging press. A pusher positions the hot bar at the pick-up station. Grip-fingers grip the bar, move it horizontally, and place the bar on the first die. Grip fingers move out. The upper die comes down and forges the bar. Knock-out pins lift the forging out of the die. A second set of fingers grip the forging, carry it over, and place it on the second die. Fingers move out as the upper die comes down and finishes the forging. Knock-out pins lift the forging. A third set of fingers grip the forging, carry it over and drop it into a chute, where it slides into a tote box.

The grip fingers are mounted on two horizontal arms that extend through the large left window of the press, with one arm back of the dies with three fingers, and one arm in front of the dies, with a matching three fingers.

In operation, the press runs continuously. The automatic feed is chain-driven from the eccentric shaft of the press to ensure accurate timing. The grip and transfer motions are mechanically generated. Thus the timing is true, regardless of speed.

The new 2,500-ton mechanical press with its one operator in attendance

The kick-out pins are operated from a cam on the eccentric shaft.

The press runs 40 strokes/min, and has made a finished forging every stroke of the press. However, the die life would be very short at this high rate, so a hot bar should feed every second stroke, making a production of 20 forgings/min, or 1,200 forgings/h.

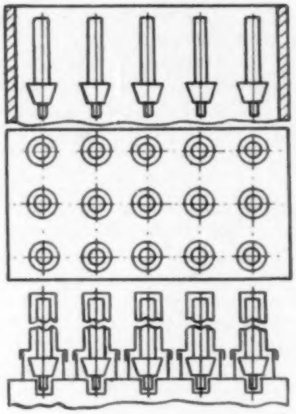
Investment founders form technical association

A new technical association serving the investment foundry industry using expendable pattern techniques for the production of industrial metal castings has been formed under the title of the British Investment Casters' Technical Association.

The objects and scope of the new organization are entirely devoted to technical aspects of investment casting and will include such activities as the preparation of specifications for materials and testing procedures, the improvement of production techniques, expansion of the application of investment castings, and the general exchange of technical information within the industry.

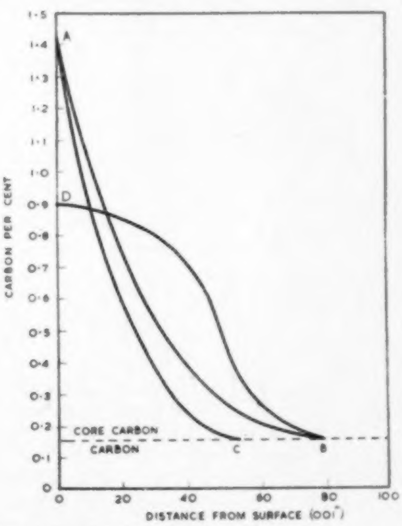
At the inaugural meeting held in London recently, which was attended by the representatives of 25 companies, the following were elected as members of Council: Mr D. H. Armitage, P I Castings (Altrincham) Ltd (chairman); Mr R. W. N. Danielsen, Deritend Precision Castings Ltd (vice-chairman); Mr W. Foyers, H & F Precise Castings Ltd; Mr G. A. Tomkinson, D. Napier & Son Ltd; Mr N. Walker, Hadfields Ltd.

Through the courtesy of the B S C R A the address of the newly formed association will be 5 East Bank Road, Sheffield, 2, and Mr J. Bolton has been appointed secretary. It is to him that companies interested in membership should write for further particulars.



4 *Relationship between pinions packed in oblong pot (top) and in individual cups (bottom)*

point instruments not only can be used for recording but are often used in conjunction with suitable valves and meters to control gas and air flow to atmosphere generators or the flow of a hydrocarbon fluid to a furnace. There are three well-known types, the principles involved being: (*a*) The measurement of the change in resistance of a wire with change in carbon content; (*b*) the formation of a dew-point water-vapour film on electrodes, which operate a relay when bridged; and (*c*) the effect of moisture on an impregnated cell.



5 *Carbon gradient in gas carburizing*

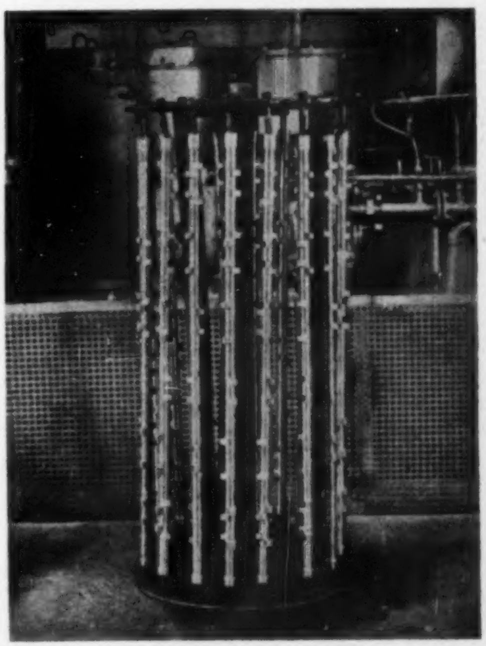
A B: Gas carburized at 925°C for T hours
A C: ,, ,, ,, ,, ,, t ,,
D B: ,, ,, ,, ,, ,, ,, ,,
followed by diffusion for T-t hours
Total treatment time, T hours

In some installations these dew-point instruments are used to measure the dew point of the atmosphere emerging from the generator, whereas in others a sample is taken from the furnace itself. In the first instance some measure of translation of results has to take place to decide a suitable heat-treatment cycle for a given load of work, whereas in the second a direct indication is given of the carburizing that is taking place in the furnace. This latter method is perhaps more suitable where furnace loads of varying sizes have to be dealt with.

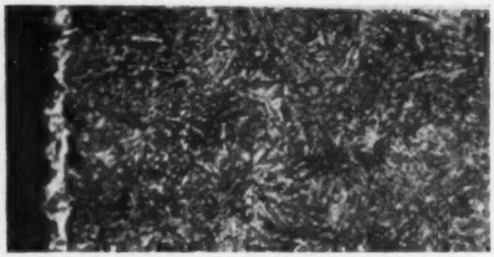
An American practice which would be a welcome development in this country involves the fitting of water-cooled heads (fig 9) to endothermic generators. This cooling head, which quickly cools the gas below its reversion temperature and prevents soot formation, would appear to improve catalyst life.

There is a growing tendency towards the use of an endothermic gas with relatively high dew point, say, —4°C to +2°C (25—35°F), and to enrich this with propane in the furnace rather than to retain the older practice of using an atmosphere of about —12°C (10°F) with a smaller propane addition. The use of higher dew-point atmospheres will reduce catalyst damage.

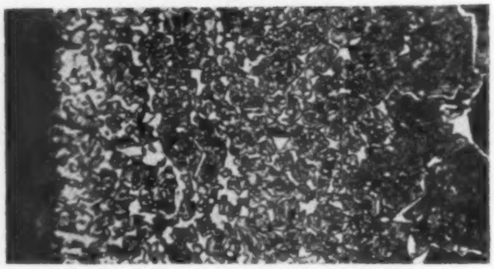
Another recent development that has taken place in atmosphere production has been the use of



6 *Vertical jigging of cam shafts* (*Wild-Barfield Ltd*)



1 $4\frac{1}{4}\%$ *Ni* 1% *Cr carburizing steel* × 500
Carburized for 6 h at 900°C in a 1% sodium carbonate compound



2 $4\frac{1}{4}\%$ *Ni* 1% *Cr carburizing steel* × 500
Carburized for 6 h at 900°C in a 5% sodium carbonate compound

moving both dust and any foreign material such as luting clay.

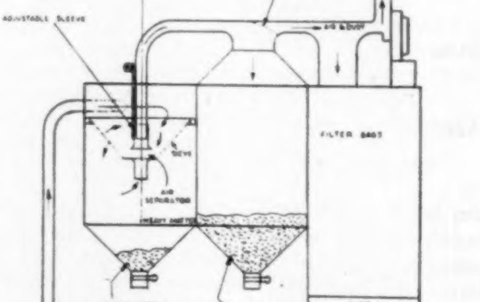
Another idea which has been tried in order to obtain more uniformity in case depth is the use of specially shaped pots designed to fit individual components or banks of components. The use of such pots as shown in fig 4 can be justified only in special circumstances and it is quite likely that in such instances gas carburizing with suitable jigging may well have an economical advantage.

Gas carburizing This method in itself is a major improvement and the desired carbon gradient can be obtained more readily than with the pack method by means of suitable diffusion cycles or control of the carbon potential of the atmosphere. This is illustrated graphically in fig 5. However, there are certain features, now regarded as commonplace, which are worthy of attention since they have emerged as a result of experience over the past few years. The two most important are jigging and gas dispersion or circulation. A typical jigging arrangement for cam shafts is shown in fig 6 and it will be seen that it is reasonably easy to obtain satisfactory gas circulation by means of distributor pipes around components which are spaced in this manner. This method of jigging, however, is not economic when a dense load of small parts has to be heat treated. The early gas carburizing furnaces were invariably of the closed-retort type in which the gas was dispersed by means of distributor tubes but the need for equipment to heat treat small parts brought forth a change in furnace design and, for small components, it is now common to use a furnace with high pressure circulation. In such equipment an adequate gas flow is obtained by means of a suitably designed baffle and work box through which the carburizing atmosphere is forced at high velocity by a centrifugal-type fan. These furnaces may be of the closed-retort or the so-called 'sealed quench' type as shown in figs 7 and 8.

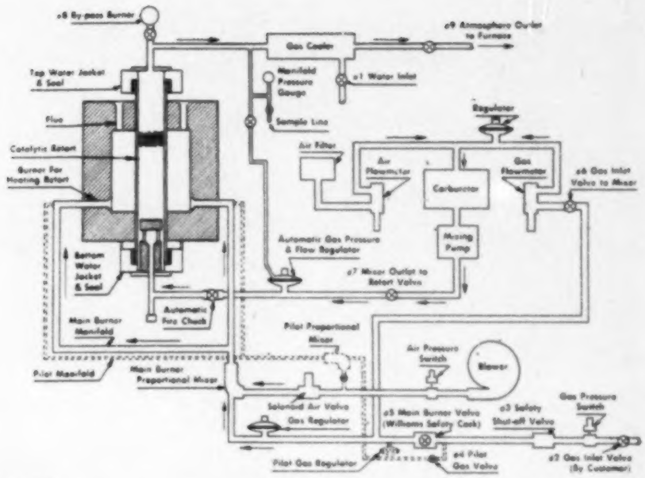
The methods of producing carburizing atmospheres are well known and the products can be divided conveniently into three sections: (*a*) Prepared town's gas prepared by passing raw town's gas over a heated catalyst which removes CO_2; (*b*) endothermic gas prepared from an air/town's gas mixture, additions of propane or butane being made in the furnace chamber; (*c*) an atmosphere generated from a hydrocarbon fluid.

Whatever the atmosphere used, adequate control of carbon potential is essential if satisfactory carburizing is to be carried out. The method now commonly adopted is by measurement of dew point, and several types of instrument are available for this purpose.

Two of these instruments are readily portable. The first, which is the frost-point mirror type, measures the condensation point of an atmosphere on a polished surface of which the temperature can be changed. The second is a pressure type, in which a gas is compressed and then the pressure released to give a cooling effect, the gas being observed in a chamber. If a fog is formed, then the dew point has been reached. By suitable pressure and temperature observations the temperature of this dew point can be ascertained. The other dew-

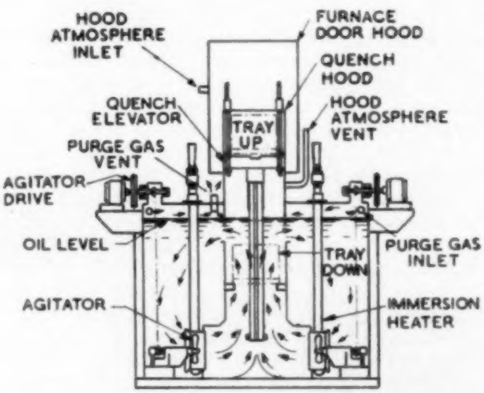


3 *K L controller for carburizing compound separation and cleaning* (*Keighley Laboratories*)



9 RIGHT *Flow diagram for endothermic generator with water-cooled head (Lindberg Engineering Co)*

10 BELOW *Oil tank circulation (Surface Combustion Corporation)*



temperatures and it is evident that some measure of success has been achieved.[2, 3, 4]

The use of temperatures above 950°C will damage conventional equipment, hence the general tendency is towards the use of medium-frequency heating equipment built into a cylindrical gas-tight chamber. This obviates the need for special retorts and element materials but the initial outlay for generator equipment will be higher. One semi-conventional furnace has been described which uses two baskets and has a working space 27½ in. dia, 39½ in. high. The atmosphere for this furnace is generated from a liquid by means of an external vaporizing tube and an atmosphere change of 100 times per hour is quoted.

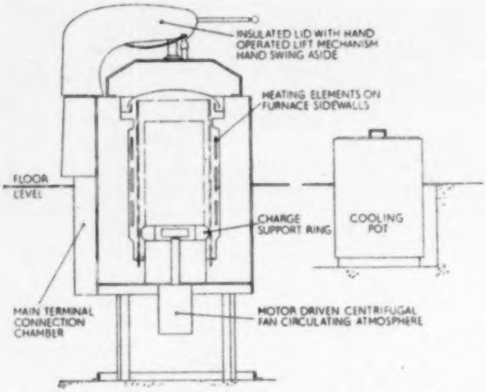
Two production furnaces, one batch and one conveyor, are reported to be in use in Russia for the carburizing of gears and it is said that a case depth of 0·032—0·047 in. (0·8—1·2 mm) is obtained in 45—60 min at 1,050°C. Table I gives a broad outline of the results quoted in Russian literature.

TABLE I *Carburizing results reported in Russian literature*

Carburizing time	Carburizing temperature, °C	Case depth (total), inches
5 min	930	—
	1,000	0·010
	1,050	—
	1,100	0·016
10 min	930	—
	1,000	0·020
	1,050	—
	1,100	0·028
1 h	930	0·018
	1,000	0·032
	1,050	0·040
	1,100	0·060
3 h	930	0·037
	1,000	0·056
	1,050	0·068
	1,100	—

The order of these results suggests that conventional carburizing times can be reduced to about one third by the use of temperatures around 1,050—1,100°C. Russian investigators have made a wide use of a steel with a composition of 0·16—0·23% C, 0·8—1·1% Mn, 1·0—1·3% Cr, ·08—0·15% Ti, in their tests. Presumably this was chosen for its restricted grain growth characteristics.

Quite rightly, there has been some apprehension regarding grain growth and size with high carburizing temperature. This fear does not seem to be shared by the Russian workers who quote some



7 *Retort type—gas carburizing furnace* (*Birlec Ltd*)

propane in preference to mains town's gas as the raw material from which the atmosphere is produced. The use of propane undoubtedly provides a more constant and reliable source of endothermic gas free from the fluctuations which are inevitable with town's gas. With bulk supplies, the use of propane is quite economical.

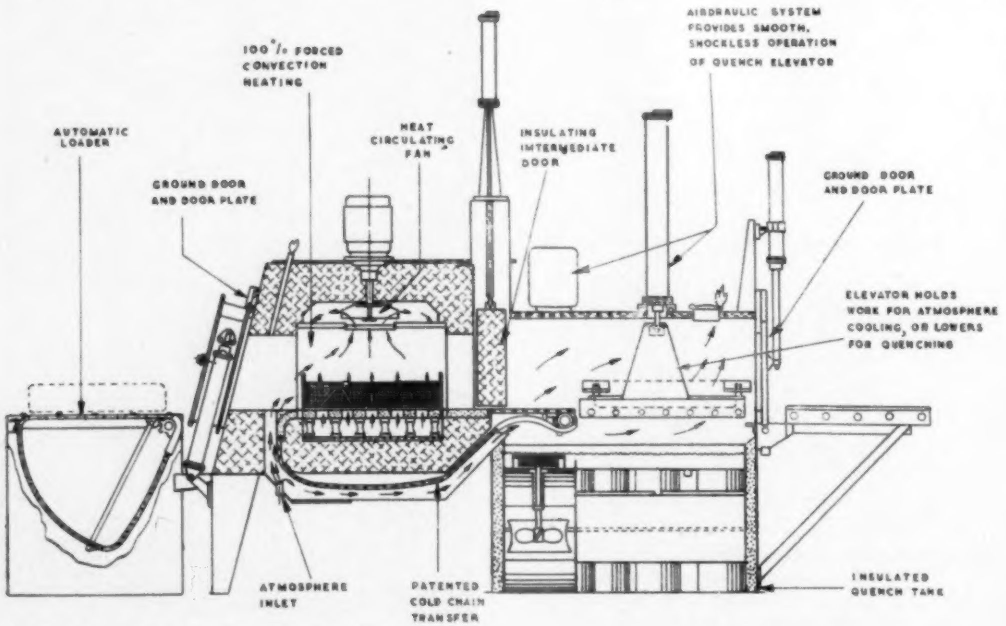
In Sweden, because of the lack of natural gas supplies, it is common to use a liquid hydrocarbon as the atmosphere source. A development here has been the use of two fluids, the one used during the initial or active part of the carburizing cycle having a high carbon potential whereas the liquid used during the diffusion period is diluted and has a lower carbon potential.

Equipment

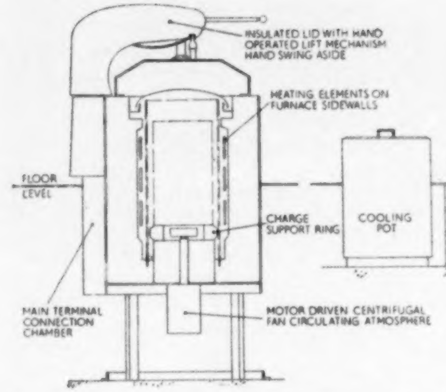
The latest developments have been more in the field of the sealed quench and the conveyor, with pit furnaces being used for special jobs and batch production. Four-, six- and eight-track pusher-type furnaces are in use, invariably heated by gas-fired or electrically-heated radiant tubes. Where more flexible equipment, suitable not only for different case depths but for other heat-treatment processes is required, then the sealed quench furnace is coming into use.

High-temperature gas carburizing

It is well known that the use of temperatures higher than the usual 900—925°C will increase the carburizing rate. Until recently little thought had been given to this because of the difficulties that would be expected if plant of conventional type was operated at temperatures around 1,000—1,100°C. Lately, however, information has been published giving details of gas carburizing at high



8 *Sealed quench furnace* (*Ipsen Industries Inc*)



7 *Retort type—gas carburizing furnace (Birlec Ltd)*

propane in preference to mains town's gas as the raw material from which the atmosphere is produced. The use of propane undoubtedly provides a more constant and reliable source of endothermic gas free from the fluctuations which are inevitable with town's gas. With bulk supplies, the use of propane is quite economical.

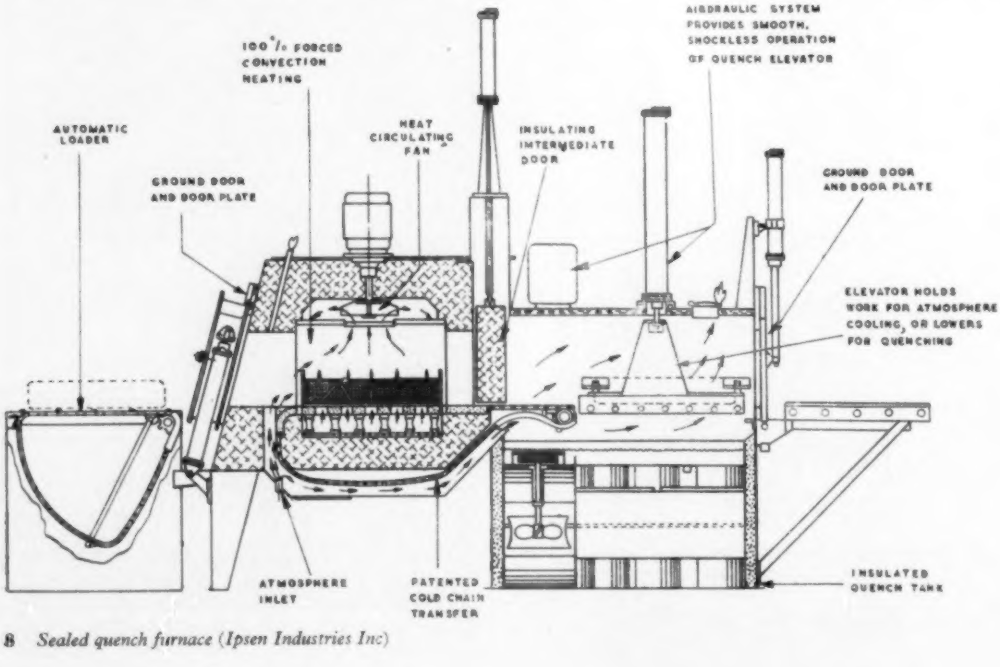
In Sweden, because of the lack of natural gas supplies, it is common to use a liquid hydrocarbon as the atmosphere source. A development here has been the use of two fluids, the one used during the initial or active part of the carburizing cycle having a high carbon potential whereas the liquid used during the diffusion period is diluted and has a lower carbon potential.

Equipment

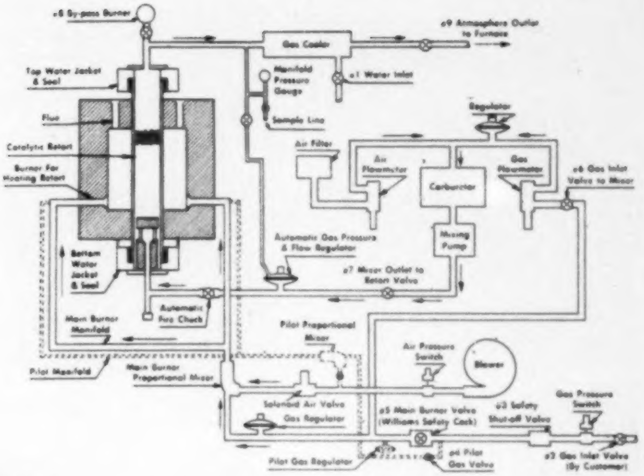
The latest developments have been more in the field of the sealed quench and the conveyor, with pit furnaces being used for special jobs and batch production. Four-, six- and eight-track pusher-type furnaces are in use, invariably heated by gas-fired or electrically-heated radiant tubes. Where more flexible equipment, suitable not only for different case depths but for other heat-treatment processes is required, then the sealed quench furnace is coming into use.

High-temperature gas carburizing

It is well known that the use of temperatures higher than the usual 900—925°C will increase the carburizing rate. Until recently little thought had been given to this because of the difficulties that would be expected if plant of conventional type was operated at temperatures around 1,000—1,100°C. Lately, however, information has been published giving details of gas carburizing at high

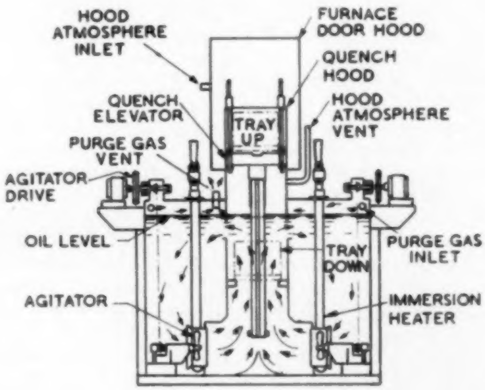


8 *Sealed quench furnace (Ipsen Industries Inc)*



9 RIGHT *Flow diagram for endothermic generator with water-cooled head (Lindberg Engineering Co)*

10 BELOW *Oil tank circulation (Surface Combustion Corporation)*



temperatures and it is evident that some measure of success has been achieved.[2, 3, 4]

The use of temperatures above 950°C will damage conventional equipment, hence the general tendency is towards the use of medium-frequency heating equipment built into a cylindrical gas-tight chamber. This obviates the need for special retorts and element materials but the initial outlay for generator equipment will be higher. One semi-conventional furnace has been described which uses two baskets and has a working space 27½ in. dia, 39½ in. high. The atmosphere for this furnace is generated from a liquid by means of an external vaporizing tube and an atmosphere change of 100 times per hour is quoted.

Two production furnaces, one batch and one conveyor, are reported to be in use in Russia for the carburizing of gears and it is said that a case depth of 0·032—0·047 in. (0·8—1·2 mm) is obtained in 45—60 min at 1,050°C. Table I gives a broad outline of the results quoted in Russian literature.

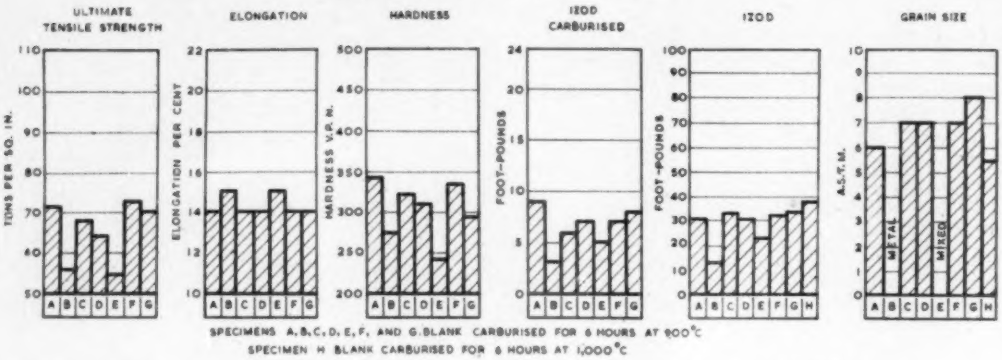
TABLE I *Carburizing results reported in Russian literature*

Carburizing time	Carburizing temperature, °C	Case depth (total), inches
5 min	930	—
	1,000	0·010
	1,050	—
	1,100	0·016
10 min	930	—
	1,000	0·020
	1,050	—
	1,100	0·028
1 h	930	0·018
	1,000	0·032
	1,050	0·040
	1,100	0·060
3 h	930	0·037
	1,000	0·056
	1,050	0·068
	1,100	—

The order of these results suggests that conventional carburizing times can be reduced to about one third by the use of temperatures around 1,050—1,100°C. Russian investigators have made a wide use of a steel with a composition of 0·16—0·23% C, 0·8—1·1% Mn, 1·0—1·3% Cr, ·08—0·15% Ti, in their tests. Presumably this was chosen for its restricted grain growth characteristics.

Quite rightly, there has been some apprehension regarding grain growth and size with high carburizing temperature. This fear does not seem to be shared by the Russian workers who quote some

TABLE III *Physical properties of En 351*



A: Direct quench
B: Single quench from 780°C
C: ,, ,, ,, 830°C
D: ,, ,, ,, 850°C
E: Double quench from 880°C and 780°C
F: ,, ,, ,, ,, ,, 830°C
G: ,, ,, ,, ,, ,, 850°C
H: Direct quench

excellent mechanical test results on test pieces of the steel mentioned when carburized at high temperatures. Some Russian figures[3] are given in Table II.

TABLE II $1\frac{3}{16}$ *in. dia test bars heated to stated temperature, held for 30 min, cooled to 870°C, oil quenched and then tempered at 200°C for $1\frac{1}{2}$ h*

Temp, °C	Y Pt, lb/sq in.	U T S, lb/sq in.	Elongation, %	Reduction in area, %	Impact, ft lb
950	153,600	183,500	10	56	83
1,000	163,600	184,900	13	63	85
1,050	185,000	200,500	12	63	90
1,100	162,100	187,700	13	63	85
1,150	146,500	167,800	10	57	79

The metallographic examination of these specimens showed a growth of austenite grains as the temperature was increased but this has not lowered the mechanical properties. The suggestion is that the austenite is homogenized at high temperature with maximum solution of alloying elements and that the titanium carbide is present as fine particles. It is said that this increase in homogenity of the solid solution exerts a greater effort than the grain size on the toughness of the steel.

In addition to the test bars mentioned above, gear-tooth strength tests have been reported. A static breaking stress of a gear tooth carburized by induction at 1,050—1,080°C is given as 12—16 tons, whereas 10—14 tons is quoted for a gear tooth which has been pack carburized at a conventional temperature. Distortion is said to be no greater with high-temperature carburizing than with pack carburizing.

Russian work[2] shows no substantial difference in grain size between specimens carburized to the same case depth at different temperatures, although the case produced at the conventional temperature tended to be coarser than that of specimens treated at higher temperatures. This is attributed to the fact that carburizing to a given depth at 900°C takes three times as long as it does at 1,050°C. It is also said, and would be expected, that the carbon gradient and surface concentration decrease as the carburizing temperature is raised.

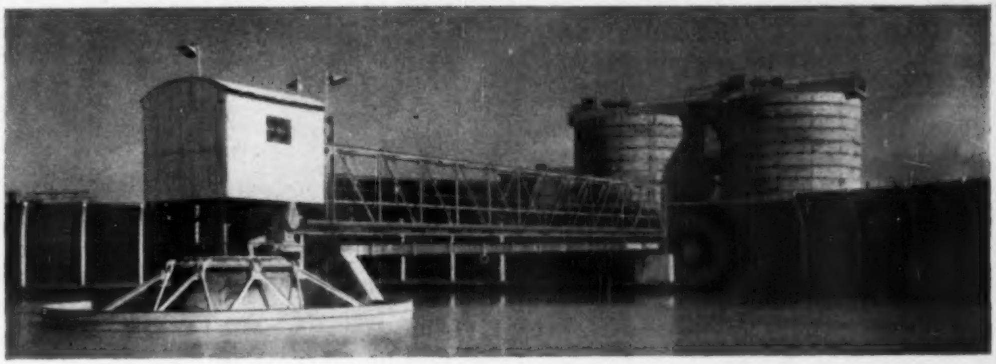
Heat treatment after carburizing

Perhaps the most significant change of thought that has occurred in the heat treatment of carburized components is concerned with the use of either single or direct quenching and the use of martempering procedures employing either hot oil or molten salt.

It is now common practice to quench direct from the carburizing operation when a sealed quench furnace is being used or, in the case of a conveyor carburizing installation, to use a low-temperature hardening zone after the carburizing operation proper. In view of the increasing tendency to use containers which hold relatively dense loads in sealed quench furnaces much attention has been given to adequate circulation in built-in oil tanks. An illustration of this is given in fig 10.

Hot-oil quenching, although well publicised in the technical literature, does not seem to be employed very often in automatic installations because of the difficulties involved with preventing oil oxidation. This has been overcome to some extent by suitable covering with protective atmospheres, and claims are now made that satisfactory oils can be obtained for use within the temperature range of

continued on page 433



One reaction system showing settling tank and two reaction tanks

World's largest sea-water magnesia plant

Steetley Co's Hartlepool Works

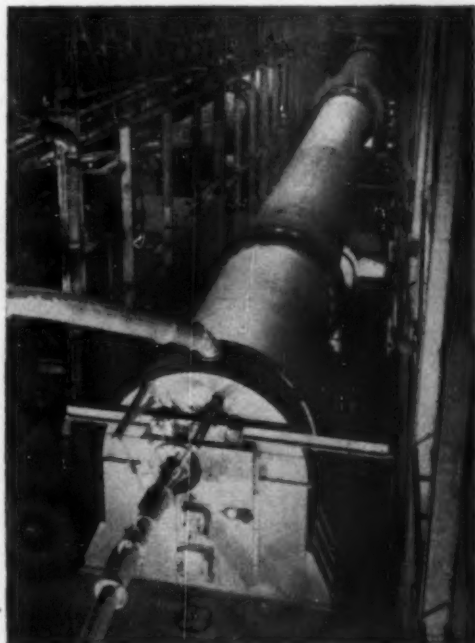
THE MAGNESIA WORKS, situated on a 24-acre coastal site at Hartlepool, Co. Durham, was inaugurated by the Steetley Co Ltd in 1937 when a pilot plant was installed in order to produce refractory magnesia by reacting burnt dolomite with treated sea water.

A full-scale plant—the world's first sea water refractory magnesia unit—was laid down in 1938, and was producing at the annual rate of 4,000 tons by the following year. Development thereafter was rapid, as large quantities of magnesia were required not only for the manufacture of high-temperature refractories but also for the production of magnesium metal when Britain's imported supplies were threatened by the war.

Production rate increases exports

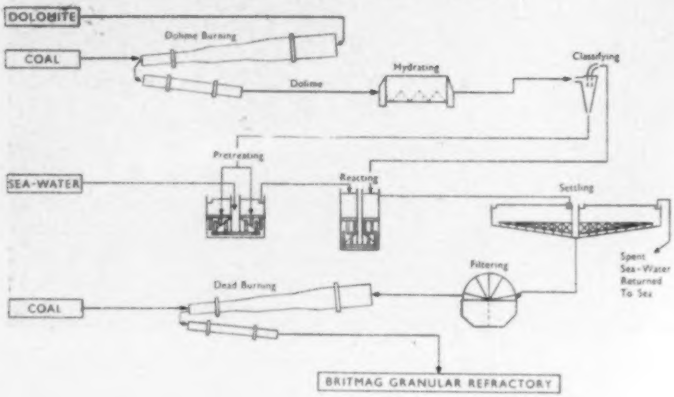
This year, the production rate has reached 150,000 tons per annum, the bulk of which will be supplied to the refractories industry, including Steetley's own brickmaking plants.

The economics of the process are such that the company is able to market magnesia at 70% of the import price and to effect an annual saving in foreign exchange of £4 million. Moreover, independence from Austrian sources has freed the British brickmakers from the previously imposed export restrictions, with the result that magnesite and chrome-magnesite bricks to the value of £1 million a year are now being exported from this country.



1 *One of the five rotary kilns in which the final product—granules of 'Britmag' is produced. The kilns, fired by pulverized coal, operate at over 1,600°C*

DIAGRAMMATIC FLOW SHEET



2 *The 'Britmag' production process showing one of the three reaction systems*

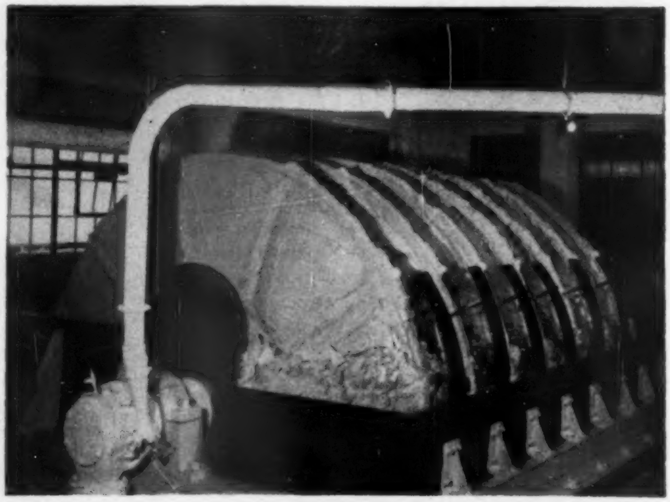
Preparation of dolime

Hartlepool was chosen as a convenient site for the new plant because of the proximity of dolomite deposits to the coast. At the company's Thrislington and Coxhoe quarries, graded dolomite is burnt in rotary kilns fired with pulverized coal to yield a magnesian lime known as dolime. Transported to the Hartlepool works in hopper-bottomed rail wagons, the dolime is slaked with fresh water to a fine dry powder in any of the five hydrator units. The hydrated product is made into a slurry for ease of handling and to facilitate mixing with sea water, and is then classified to remove the impurities introduced from the fuel during calcination of the dolomite.

Sea-water process

Sea water is drawn by centrifugal pumps through five 950-ft-long cast-iron pipelines and stored in four tanks having a total capacity of 8 million gal. These storage tanks ensure a steady flow of sea water through the plant, whatever the state of the tide. The five centrifugal pumps, operating at 25-ft suction, are driven by 600-h p, 2,750-volt motors and are all controlled by one man from a central control panel. This panel also indicates flow rates in other sections of the plant and thus permits close supervision of the process.

In order to remove calcium bicarbonate from the sea water, the storage tanks feed into five pre-treatment tanks or hydro-treators, where a small



3 *Rotary disc vacuum filter. The washed sludge contains about 50% solids after filtering and this is transferred to the rotary kilns for calcination*

proportion of dolime is introduced. The hydrotreators are fitted with variable-speed central drive and diaphragm sludge pumps.

After treatment, the sea water is pumped into reaction tanks and here it is mixed with the classified dolime slurry, and precipitation of magnesia takes place. The chemical reaction is:

$$\underset{\text{Dolime}}{CaO, MgO} + \begin{cases} MgSO_4 \\ MgCl_2 \end{cases} + 2H_2O \rightarrow \underset{\text{Magnesium hydroxide}}{2Mg(OH)_2} + \underset{\text{Spent sea water, calcium salts}}{\begin{cases} CaSO_4 \\ CaCl_2 \end{cases}}$$

There are three reaction systems at the Hartlepool works, each consisting of two cylindrical reaction tanks fitted with agitators, and one settling tank equipped with continuously rotating thickener mechanism. The most recent settling tank, which was completed early this year, is 255 ft dia. It incorporates a cantilevered thickening mechanism, is the largest centre-drive unit operating in Europe and has a capacity of 3½ million gal. Thirty million gallons of sea water are processed daily in the three reaction systems.

When the dilute suspension of magnesium hydroxide has settled in the tanks, it is drawn to a centre well by means of rotating rakes and pumped out as a sludge to washing tanks containing sea water. The washed sludge is next filtered on a battery of rotary vacuum disc filters (fig 3).

The filter cake, containing about 50% of solids, drops on to a moving conveyor belt which transfers it to rotary kilns for calcination. There are five rotary kilns, the largest being 250 ft long; each is equipped with an associated rotary cooler (fig 1). The kilns are fired by pulverized coal and operate at a temperature of over 1,600°C. After cooling, the granules of 'Britmag'—as the final product is called—are ready for bagging or despatch in bulk to the brickworks and steelworks. The product contains a minimum of 90% magnesium oxide and is virtually inert to the action of atmospheric moisture. An average percentage composition is: SiO_2, 2·1; Al_2O_3, 1·4; Fe_2O_3, 1·4; CaO, 2·7; MgO, 92·4.

Electrostatic dust precipitators give a clean kiln gas discharge of 99·5% efficiency.

Uses of 'Britmag'

'Britmag' is supplied from Hartlepool to Steetley's refractory brick division and to other British manufacturers of refractories. It finds its most extensive use in the production of magnesite and chrome-magnesite bricks, the latter containing about 30% magnesia, which are used for the linings of open-hearth steel melting furnaces. In granular form, it is employed as a fettling material on steel furnace hearths. Another important application is for the lining of cement and lime kilns, where the magnesite content of the refractory is raised to between 60 and 80% to meet conditions of severe abrasion.

In 21 years, sea-water magnesia has evolved from the research laboratory to the full-scale commercial plant, an achievement which owes much to the pioneering work of the Steetley Co, whose Hartlepool works is the largest plant of its kind in the world. As well as being cheaper the product is in some respects superior to that of natural magnesite in that its composition can be adjusted to meet the special requirements of the user.

Developments in surface hardening

continued from page 430

150—200°C. It is more usual, however, to use a molten-salt bath for the martempering technique and to station this as a separate unit away from the carburizing or re-heating furnace. There are one or two installations where a molten-salt quench has been built into the furnace unit, but in these special precautions have been taken to avoid salt fume passing back into the furnace chamber and causing contamination of the carburizing gas or damage to the furnace elements. The usual methods of avoiding these difficulties are to provide an exhaust at the quench chute and to arrange the flow of carburizing gas so that it opposes the ingress of the salt fume.

With increasing use of low-alloy and controlled grain-size steels, there is no doubt that direct quenching and martempering will gradually supersede the more conventional text-book double-quench procedures. Adequate metallurgical properties with much less distortion can be obtained on such steels by the use of these simplified quenching procedures. Table III gives some results which were obtained on 0·564 in. dia tensile and 0·450 in. dia impact test pieces made from an En 351 carburizing steel. All of the test specimens were oil-quenched.

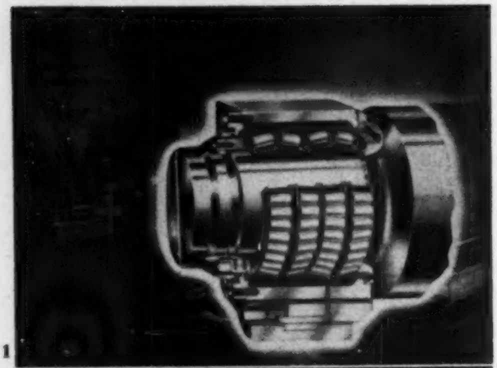
References

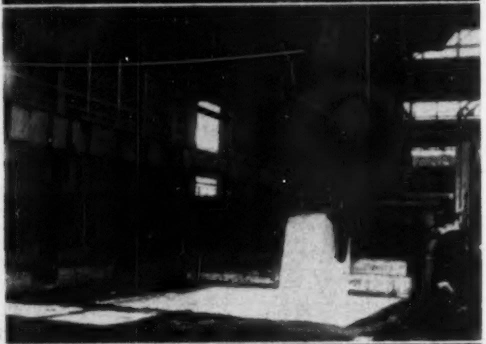
(1) Rosenthal and Manning, *Trans Amer Soc Metals*, 1947, **39**, 801-815.
(2) Shuval *et al*, *Metallovedenie i Obrabotka Metallov*, 1956, **2** (6), 49-52.
(3) Assonov *et al*, *Vestnik Mashinostroeniya*, 1954, **34** (6), 56-60.
(4) Tarasov and Stetsenko, *Ibid*, 1954, **34** (7), 50-52.
(5) Chenault and Mohnkern, *Metal Progress*, 1953, **63** (4), 97-105.
(6) P. M. Unterweiser, *Iron Age*, 1957, **179** (18), 91-93.

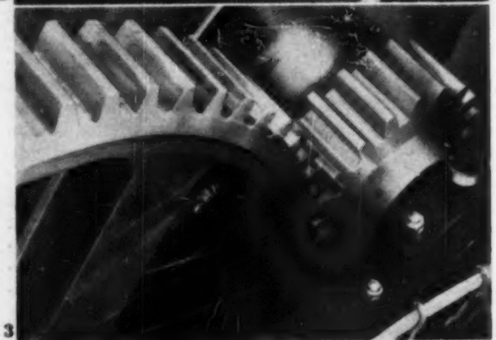
to be continued

Steelworks lubrication

A SERIES OF FILMSTRIPS, *with accompanying commentaries, has been produced by Shell-Mex and B P Ltd in association with the British Iron and Steel Federation to cover the various aspects of lubrication in steelworks. There are five in the series:* (1) *'Friction and lubrication'*; (2) *'Bearings, gears and slideways'*; (3) *'Methods of application'*; (4) *'Selection of lubricants'*; (5) *'Special applications of lubricants.' Copies of the filmstrips, which are in colour, may be borrowed from the Federation's training officers or the local offices of Shell-Mex and B P Ltd*

1


2


3


4


Typical illustrations from various filmstrips show:

1 *Roll neck bearing on the horizontal rolls of a slabbing mill. Precision of such bearings is best preserved by use of suitable greases*

2 *High viscosity application—low speeds, heavy loads and high temperatures*

3 *Spur gears. Lubrication can be carried out in a variety of ways, such as by an oil bath or by means of a spray*

4 *Gear teeth showing pitting. Progressive pitting usually occurs through overloading but can occur through the use of too light an oil*

NEWS

New laboratory at Aston Chain & Hook Co

A NEW £15,000 laboratory block has been opened at the Erdington (Birmingham) works of the Aston Chain & Hook Co Ltd, non-ferrous metal engineers. The company produces in the main extruded, rolled and drawn copper section bars, and in addition manufactures rolled brass, copper and bronze strip, wire, metal pressings and chain.

With such a range of products it was considered essential to provide a competent technical control at all stages of production. This was the original function of the technical department and it began in 1938 with the establishment of a small analytical laboratory for control of the casting shop. During the following years the technological requirements of the industry have become more demanding, and this has led to the expansion of the department, which, as the Development Department, has now assumed responsibility for process control, inspection, work study, factory layout, and product and process development work.

New president of B S I

At the annual general meeting of the British Standards Institution held in London last month, Mr R. E. Huffam, United Kingdom co-ordinating director of Unilever Ltd and chairman of B S I's Finance Committee since 1952, was elected as the Institution's new president. He was recently also elected chairman of B S I's General Council, and thus succeeds Sir Herbert Manzoni, city engineer of Birmingham, in the joint tenure of the Institution's two most senior offices.

Succeeding Mr Huffam as chairman of B S I's Finance Committee is the Hon Geoffrey Cunliffe (deputy chairman and managing director of the main companies in the British Aluminium Group), who has been a member of that committee since 1952.

The two immediate past presidents, Sir Herbert Manzoni and Sir Roger Duncalfe, were elected deputy-presidents of the Institution, and Mr John Ryan (vice-chairman of the Metal Box Co Ltd) was re-elected to this office.

Mr R. E. Huffam

The appointment by the General Council of a new chairman of the Council for Codes of Practice was announced. The new holder of this office is Mr A. C. Hartley, the well-known consultant who is already chairman of the Codes of Practice Committee for Mechanical Engineering and of the Mechanical Engineering Industry Standards Committee. He succeeds Sir Allan Quartermain.

The chairmen of the four Divisional Councils continue in office. They are Mr Paul Gilbert (Building), Mr T. W. Howard (Chemical), Sir Stanley Rawson (Engineering) and Mr L. F. Cockroft (Textile).

B S I annual report, 1957-58

Review of the year

Reviewing the B S I's annual report for 1957-58 the retiring president, Sir Herbert Manzoni, referred to two outstanding trends: the enlarged scope and importance of international collaboration on standards and the increase in public recognition of the Institution's work. There was a record increase in the number of new subscribing members—from 9,000 to nearly 10,000 during the year. This success was accompanied by a considerable number of agreements by existing members to pay increased subscriptions.

Awards for essays on corrosion

The Education Panel of the Corrosion Group, with the approval of the Council of the Society of Chemical Industry, established in 1955 a competition designed to encourage those who are still in the early stages of their career to take an interest in corrosion science and to express their ideas in writing. With the support of industrialists interested in the application of corrosion science in industry, a prize of the value of 25 guineas will again be awarded this year for an essay or paper on any aspect of corrosion of metals and its prevention.

Essays are invited from persons aged not more than 27 years on the closing date. A length of about 4,000 words is suggested. Judgment of the entries by judges appointed by the Education Panel Committee will be based on the evidence shown of the candidate's critical faculty and originality of thought, and on technical and literary excellence generally. Results of original research may be incorporated, but this is not essential; entries may consist, for example, of surveys of knowledge in a particular field, discussion of practical problems, and suggestions for future developments in research, in application of knowledge, or in organization of corrosion-preventive measures.

The closing date for receipt of entries is March 31, 1959. Details may be obtained from the Society of Chemical Industry, 14 Belgrave Square, London, S W 1.

High-tensile aluminium bronze alloys

A new publication, 'The development of high-tensile aluminium bronze alloys for marine propellers,' has been issued by the Mond Nickel Co Ltd.

The excellent mechanical properties of the complex aluminium bronze alloys containing nickel and their resistance to corrosion and erosion have led to a remarkable increase in their use for many types of marine propellers with outstanding economic advantages.

The illustrated publication, based on a paper presented to the Institute of Dutch Shipbuilders and Shipowners in 1957, describes the various technical and production factors involved and how they must be applied in practice if satisfactory results are to be obtained. The results of preliminary sea trials are also given. The publication is available, free of charge, from the Mond Nickel Co Ltd (Publicity Department), Thames House, Millbank, London, S W 1.

B W R A annual general meeting

British Welding Research Association held its annual general meeting last month, at which three new Council members were elected. Dr R. Beeching, the technical director on the Main Board of Imperial Chemical Industries Ltd; Mr J. M. Willey, director and general manager of Murex Welding Processes Ltd; and Mr T. M. Herbert, the director of research, British Railways Division of the British Transport Commission. Mr J. Strong, this year's president of the Institute of Welding and executive director of British Oxygen Gases Ltd, will represent the Institute on the association's Council during the year 1958-59.

Annealing installation in South America

The Incandescent Heat Co Ltd has recently been awarded a contract worth more than £500,000 for a large coil-annealing installation at the new steelworks of the Sociedad Mixta Siderurgia Argentina (SOMISA). The order, obtained against strong continental competition, is for 25 single-stack coil-annealing furnaces with 72 bases, 32 forced cooling hoods, and three exothermic gas atmosphere plants each rated at 10,000 cu ft/h. The furnaces are built to the design of the Lee Wilson Engineering Co Inc, of Cleveland, U S A, for whom Incandescent are manufacturing licensees. The plant will handle coils up to 60 in. diameter in stacks up to 168 in. high, and will anneal annually 300,000 tons of cold reduced sheet and tinplate. The equipment will be manufactured and completely assembled at the Smethwick works of the Incandescent Heat Co Ltd. The order will be completed within 12 months.

The Sociedad Mixta Siderurgia Argentina is a semi-state enterprise which, under the national steel plan, is building a large integrated steelworks at San Nicolas, near Rosario. The works is scheduled for completion by 1959, but small-scale operation will begin this year. The plant will have an initial capacity of 600,000 tons of steel per year, which will be increased eventually to 1,000,000 tons. In addition to hot and cold rolled sheet, strip and tinplate, the works will produce billets, plates, rails and sections.

George Turton Platts & Co Ltd

Forging with 'Stellite'

At the works of George Turton Platts & Co Ltd, rolling stock buffers are being clipped to shape and sized by 'Stellite'-faced top tools. Runs of 10,000 are quite common, this being ten times the life obtained from normal steels. Temperature of operation 800°C in a 300-ton press. The picture shows a range of tools, all of which can be refaced with 'Stellite' when worn. Tools used for clipping buffer heads between 13 in. and 18 in. diam

NEW NAMES AND ADDRESSES

THE TELEPHONE NUMBER of **Wild-Barfield Electric Furnaces Ltd** has been changed to Watford 26091.

Acheson Industries (Europe) Ltd, formerly of 18 Pall Mall, has moved to offices in one of the City's newest buildings. Its address now is Acheson Industries (Europe) Ltd, 1 Finsbury Square, London, E C 2 (MONarch 5811).

The growth of the Acheson organization in Europe has necessitated certain administrative changes and it is essential that adequate space should be available for future expansion.

Birlec Ltd and **Efco Ltd,** electric furnace manufacturers, announce that negotiations between them for the formation of a new company, to take over certain sections of their business, have reached an advanced stage. It is intended that the new company shall be called Birlec-Efco (Melting) Ltd, and that its offices shall be near Birmingham, at Aldridge, Staffs.

The intended scope of the company is the design and supply of all types of electric melting furnaces for the ferrous and non-ferrous metals industries, together with smelting furnaces and induction-heating equipment.

The personnel of the company will be drawn from the appropriate divisions of Birlec and Efco, thus combining in one organization the specialist techniques and extensive experience of both companies. Birlec and Efco will continue independently to manufacture their respective heat-treatment furnaces and other plant.

Bottogas Ltd, supplier of liquefied petroleum gases, is changing its name to Shell-Mex and B P Gases Ltd. The registered office will continue to be at Cecil Chambers, 76–86 Strand, London, W C 2.

The new name reflects the closer integration which is taking place with its parent group, Shell-Mex and B P Ltd. Products will continue to be marketed under the brand name 'Bottogas.'

Impermeable graphite for nuclear reactors

Graphite which is completely impermeable to gases and highly resistant to gaseous corrosion has been developed for nuclear applications by the Research Laboratories of the General Electric Co Ltd and was being demonstrated for the first time at the 1958 'Atoms for Peace' exhibition at Geneva last month.

Graphite as used to slow down the fast neutrons in a nuclear reactor is a porous material permeable to gases. The graphite manufacturer relies on this permeability to prevent the disruption of his product during the intensive heat treatments associated with the standard graphite-making process. Some reactor-grade graphites undergo

an impregnation treatment which increases the final density but this does not effectively reduce the porosity.

Permeable graphite has several practical disadvantages. In the first place, corrosion by hot gases can occur within the body of the graphite moderator blocks and is not confined to their geometrical surface. In fact, every gramme of graphite exposes nearly 1/2 m^2 of surface and in a reactor containing 1,000 tons of graphite this surface is of considerable importance. Secondly, the permeability of the graphite permits the escape of gas from the coolant channels in the reactor. An impermeable graphite would permit a design in which the fission products are continuously pumped from the fuel contained within an impervious graphite tube and the coolant gas (outside this tube) remains uncontaminated. This arrangement has very appreciable advantages.

A completely impermeable graphite could have quite novel applications in reactor technology, and could also prove attractive for use in carbon dioxide, water, sodium and hydrogen-cooled reactors. For example, it might be possible to take advantage of the low neutron absorption and extreme heat resistance of graphite and use it as a canning material in place of magnox, beryllium or stainless steel. The brittle nature of graphite could well be a limiting factor, but current research work by G E C is exploring the mechanical properties of graphites under nuclear irradiation and it may be that this problem will not be as serious as at first thought.

Impermeable graphite behaves like metal

The G E C Research Laboratories have undertaken two development programmes in this field; one to reduce the permeability of existing moderator graphites by an impregnation process, and the other to manufacture a completely impermeable material. In the latter case it has been found necessary to abandon the existing process for making graphites and the carbon atoms are built up in an entirely novel fashion. The first process has resulted in considerable reductions of the permeability of existing graphites and a millionfold improvement has been found possible. In spite of this improvement, however, gas can still enter the interior of this graphite. The totally impermeable material, on the other hand, behaves like a metal and has a gas displacement corresponding to the geometrical volume of the specimen, *i e* gas does not have access to the interior.

The demonstration at Geneva exhibited a tubular graphite element which is heated by the passage of an electric current. The temperature is maintained at slightly below 600°C so that the tube is just visibly red hot. The interior of the specimen is pressurized with carbon dioxide. Research work has shown that graphite does not corrode under these conditions. Since corrosion would rapidly increase the permeability, a demonstration that the impermeable nature is preserved is also a convincing proof of corrosion resistance. To illustrate the low permeability, the specimen is mounted in an evacuated container and the rate of flow through the pump is monitored. The pressures inside and outside the specimen are shown on the appropriate gauges.

Most applications of a totally impermeable graphite call for a method of welding or joining graphite to graphite, or graphite to metals. The exhibit demonstrates such a joint operating under stress at reactor temperatures and, at the same time, acting as an impermeable barrier to the carbon dioxide gas.

PEOPLE

THE DIRECTOR of the British Welding Research Association, **Dr Richard Weck,** has accepted an invitation from the American Society for Metals to lecture to its Seminar on Residual Stresses this month at Cleveland, Ohio, during the 40th national congress of the Society. Some of the aspects of residual stresses to be discussed in the seven lectures are their origin, measurement and definition, as well as their effects on strength, fatigue strength, deformation, stability, corrosion, brittle fracture and stress relieving.

Dr Weck, a mechanical and civil engineer, who is only 45, has an international reputation for his knowledge of residual stresses and fatigue, and has been chairman of the International Institute of Welding's Commission on Residual Stresses since 1948. He graduated as a civil engineer in Prague before obtaining his Ph D at Cambridge where he lectured for many years, part of the time organizing refresher courses for professional engineers. He is also the author of many technical papers on stress relieving and fatigue.

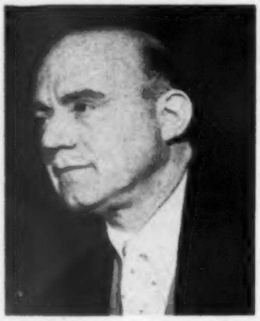
Mr G. Morris

Mr G. Morris has been appointed foundry works manager of Head Wrightson Iron Foundries Ltd, a subsidiary of Head Wrightson & Co Ltd. He was formerly with the South Durham Steel & Iron Co, and joined Head Wrightson in 1941 to work in the metallurgical laboratories. For the last five years he has been assistant to the foundry works manager.

Mr R. J. Gresley, A M I E E, has recently been appointed chief engineer of the Power and Distribution Transformer Division of the Gresham Transformer Group.

Mr Gresley, aged 37 years, was born in Dublin and educated at Denbigh Grammar School, North Wales. In 1937 he was apprenticed to Ferranti Ltd, in the power transformer department. In 1943 he joined the Royal Air Force, serving as an engineer officer. He returned to Ferranti and from 1953 to 1957 was chief engineer in the distribution transformer department. During this period he was particularly concerned with the use of cold grain-oriented steel in distribution transformers and also with the use of Class 'H' insulation. He was the part author of a paper on the use of aluminium in transformers, presented at the symposium held by the Aluminium Development Association in May, 1957.

In 1957 he transferred to the power transformer department to gain further experience in the design of large transformers, and continued in this work until joining Gresham Transformers Ltd in July, 1958.



Mr J. Hodkinson

Mr J. Hodkinson has been appointed a director of Wickman Ltd with overall responsibility for the company's machine tools export interests. He will retain his present appointment as managing director of Machine Tools (India) Private Ltd (a Wickman associated company), which he assumed upon joining that company in June, 1954.

Mr Hodkinson is well known in machine-tool circles in this country and India; prior to joining Wickman Ltd he had held appointments with the Associated British Machine Tool Manufacturers' Indian company and Craven Bros (Manchester) Ltd. During the war he was deputy director-general (tools) and machine-tools controller with the Government of India.

Mr E. G. Pickering, a joint managing director of Johnson, Matthey & Co Ltd, died last month after a prolonged illness.

Mr F. A. Spence-Brown, also a joint managing director of the company, died suddenly last month.

Mr Richard Turner has been appointed a managing director of Johnson, Matthey & Co Ltd. He relinquishes his position of managing director of Mallory Metallurgical Products Ltd, a subsidiary company, but remains a director.

Mr J. Royce

Mr James Royce, the well-known furnace designer, has recently been appointed to the board of Hedin Ltd.

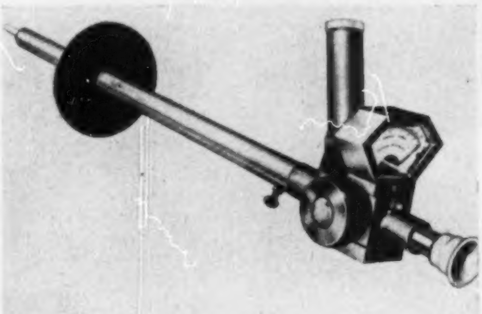
Mr R. F. Hatto, sales director of Wolf Electric Tools Ltd, has retired from business, thus terminating a long association with the company.

NEW PLANT

Molten-metal temperature measurement

Foster Instrument Co is now marketing a pyrometer known as the Foster-Platt optical immersion pyrometer which opens up a new approach to the temperature measurement of molten metals in crucibles and ladles. It overcomes the limitations imposed on the normal optical pyrometer and is simple to operate. Accurate readings can be obtained in a matter of seconds.

The optical axis of a disappearing filament type of optical pyrometer is extended in a light-tight tube sealed at its outer end with a refractory sheath. On immersing



1 *Foster-Platt optical immersion pyrometer*

in a bath of molten metal its inner end assumes in a few seconds the temperature of the bath, and since the image of the pyrometer filament is permanently superimposed, a reading can be obtained quickly and accurately regardless of the type of alloy being tested. In most non-ferrous metals the refractory sheath will withstand up to 150 immersions and 50 in cast iron.

In the event of the sheath breaking, a new one can quickly be fitted at a small cost. The instrument is self-contained, having dry batteries with special high-current cells contained in the tubular handle.

Automatic temperature-scanning equipment

In many processes it is desirable or even essential to keep a check on a large number of temperature points, but in the majority of continuous processes the indication serves no useful purpose as long as the temperatures are at the desired values. To have one instrument on each point would be rather extravagant both in the cost of the instruments themselves and in the space required to house them. It is preferable, therefore, for one equipment to be used to monitor all points and this is the function of the scanning equipment Type BB1 developed by Fielden Electronics Ltd.

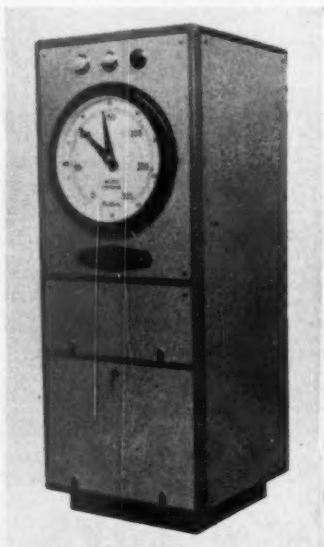
The temperature is indicated on a large dial approximately 2 ft diameter and around the periphery of this dial are the point numbers, *e g* 1–50. A motorized scanning switch enables the equipment to examine each point in turn and a clear perspex pointer, tipped black, indicates the number of the point under examination at any one time.

It cannot be expected that the desired value for all points will be the same and with this equipment it is possible to have a different set point for each of the 50 variables. The value of the set point is shown by the position of a red pointer and this can be adjusted by a small potentiometer under the indicator bezel and in line with the temperature point number.

The actual value of the temperature is shown by the position of a green pointer and the measuring circuit is potentiometric. Thermocouples are used as the detecting elements and the output voltage of the thermocouple is compared with a stable d c voltage by means of a self-balancing servo-mechanism.

On a large plant certain of the temperature variables may have to be held to closer tolerance than others and to cope with such a situation the equipment has three tolerance bans which can be adjusted to required values. Any number of temperature points can be allocated to any of these three bands. This will then enable the more important variables to give an alarm should they deviate by more than, say, 2%, others may be set to give an alarm should they deviate by more than, say, 5%, and the least important to give an alarm on a deviation of perhaps 10%.

In normal operation the equipment will scan the 50 points in sequence, the red pointer will balance to the desired value and the green pointer will balance to the actual value. If the difference between these pointers is more than the pre-fixed amount for that particular point, then the scanning switch will stop and the signal lamp corresponding to the particular tolerance band will be illuminated. The scanning switch can be restarted either by bringing the temperature to within the pre-fixed tolerance band or by manually switching the scanner to the next point in the sequence. Manual override is possible by means of a handle provided on the front panel of the instrument and this enables any temperature point to be indicated at will without waiting for the scanner to reach that point in its normal sequence. Push-buttons are also provided which will stop and start the scanning switch so that this can be arrested on a particular point for any desired length of time.



2 *Fielden automatic temperature-scanning equipment*

CLASSIFIED ADVERTISEMENTS

FIFTEEN WORDS for 7/6d. (minimum charge) and 4d. per word thereafter. Box number 2/6d., including postage of replies. Situations Wanted 2d. per word.

Replies addressed to Box Numbers are to be sent, clearly marked, to Metal Treatment and Drop Forging, John Adam House, John Adam Street, London, W.C.2.

SITUATIONS VACANT

METALLURGIST required by Drop Forging Co in Birmingham, to control small laboratory. Responsibilities will include forging temperature control, analysis and testing of carbon, alloy and stainless steels, the supervision of heat treatment and the investigation of production problems. The salary offered will be in the range of £850 to £950 per annum, according to experience. Applicants aged 25-35 years, of at least L I M standard, are invited to apply in the strictest confidence, stating age, experience and salary required to: Box M R 110, METAL TREATMENT AND DROP FORGING.

METALLURGIST required for research and development laboratory. Must be fully conversant with heat-treatment techniques and preferably have a knowledge of metallography and physical methods of analysis. Permanent position with good future prospects. Pension scheme. Apply in writing to: Chief metallurgist, Wild-Barfield Electric Furnaces Ltd, Elecfurn Works, Watford By-pass, Watford, Herts.

WEST MIDLANDS GAS BOARD

INDUSTRIAL GAS REPRESENTATIVES

With the increase in the development and utilization of gas for Industrial purposes, further appointments will be made in the Midlands to meet the demand.

The work will involve investigation and submission of schemes for the use of gas for furnace heating and other industrial purposes.

Applications are invited from candidates with an appropriate university degree, Higher National Certificate or similar qualification. Experience of Industrial Gas is not essential as adequate training will be given.

The salary during the training period will be in accordance with Grade APT 7 (£705-£785 per annum) of the National Salary Scales for Gas Staffs, and subject to satisfactory completion of the training, appointment to a permanent post on a higher grade will be made. The appointments are pensionable and subject to medical examination.

Applications stating age, education, qualifications and experience, should be addressed to the Industrial Relations Officer, West Midlands Gas Board, 6 Augustus Road, Edgbaston, Birmingham, 15.

J. SWAN,

Secretary to the Board.

EDUCATION

Bristol Education Committee

THE COLLEGE OF TECHNOLOGY

Short Courses of Lectures will be held at the College dealing with following subjects:

1. **"The Selection of Engineering Materials."** Friday/Saturday, November 14/15th. Fee £2 2s.
2. **"Digital Computers and their Applications to Machine Tool Control."** Friday/Saturday, November 28/29th. Fee £1 1s.

Application forms and details from Organizer of Short Courses, College of Technology, Bristol 7.

MACHINERY FOR SALE

EFCO MUFFLE FURNACES, 18 kW, 1,200°C, 400 volts, three-phase, 50 cycles, complete with Electroflo temperature recorder and controller. Condition as new. Whitefield Machinery & Plant Ltd, Cobden Street, Salford 6. Tel: PEN 4746.

'SERCK' OIL COOLER, 750,000 BTU/hr. 1-ton capacity hoist block, complete with swing jib arm suspension. —Whitefield Machinery & Plant Ltd., Cobden Street, Salford, 6. Tel.: PEN 4746.

INDEX TO ADVERTISERS

Published by the Proprietors, INDUSTRIAL NEWSPAPERS, LIMITED, John Adam House, 17/19 John Adam Street, Adelphi, London, W.C.2, and Printed in Great Britain by F. J. PARSONS, LTD., London and Hastings.

metal
atment

Vol. 25 : No. 157 OCTOBER, 1953 Price 2/6